The experimental axion search

Helioscope search, micromegas detectors and decay search

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BNL 22nd August 2013

Outline

The axion and direct experimental searches

The CAST experiment

Towards a new generation axion helioscope : IAXO

Micromegas detectors. Detection principle, performances, discrimination capabilities, technology development (bulk, microbulk, resistive, piggyback), Underground Rare events, simulation and characterization, high rate applications.

A large spherical TPC for axion searches.

A new light boson arising from QCD theory

QCD predicts violation of CP in strong interactions

$$\mathcal{L}_\theta = \frac{g^2\bar{\theta}}{32\pi^2} G^{\alpha}_{\mu\nu}\tilde{G}^{\alpha\mu\nu}$$

Bad agreement between theoretical and experimental values for the electric dipole moment of neutron

$$\Rightarrow \bar{\theta} < 10^{-9}\, e\cdot cm$$

Why is $\bar{\theta}$ so small ?

$$d_n(theory) \approx 10^{-16}\, e\cdot cm$$
$$d_n(\text{exp.}) < 6.3\times 10^{-26}\, e\cdot cm$$

$$\bar{\theta} = \theta + Arg(\det M)$$

Peccei-Quinn introduced the axion field to solve this problem

$$\mathcal{L}_a = \left(\bar{\theta} - \frac{a(x)}{f_a}\right)\frac{1}{f_a}\frac{g}{8\pi} G_a^{\mu\nu}\tilde{G}_{a\mu\nu}$$

The axion properties

- Neutral pseudoscalar
- Practically stable
- Very low mass
- Very low cross-section
- **Coupling to photons**

The theory predicts one unique parameter (scale factor) to describe the axion.

$$g_{a\gamma} = \frac{\alpha}{2\pi}\left(\frac{E}{N} - \frac{2}{3}\frac{4+z}{1+z}\right)\frac{1+z}{z^{1/2}}\frac{1}{m_\pi f_\pi} m_a$$

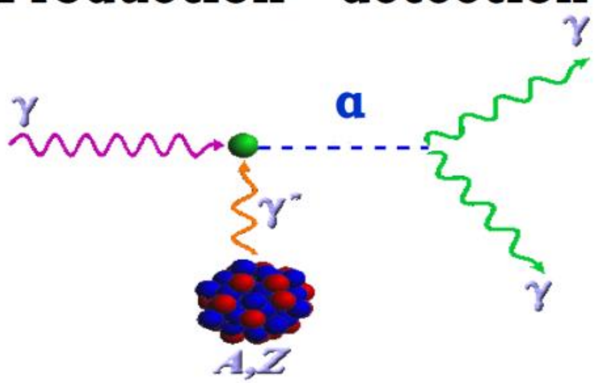
Mass depends on this parameter and it needs to be determined experimentally.

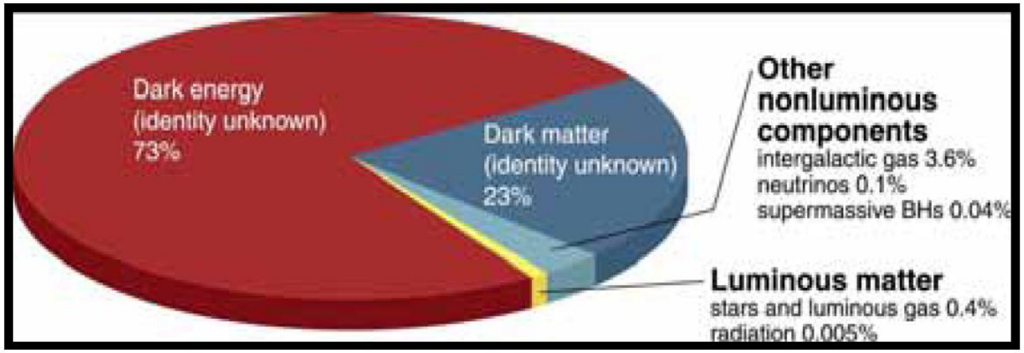
$$m_a = 6eV\,\frac{10^6 GeV}{f_a}$$

$$\Omega_\alpha \approx \left(\frac{5\mu eV}{m_\alpha}\right)^{7/6}$$

If the axion mass is small enough could contribute to the content of Cold Dark Matter of the Universe.

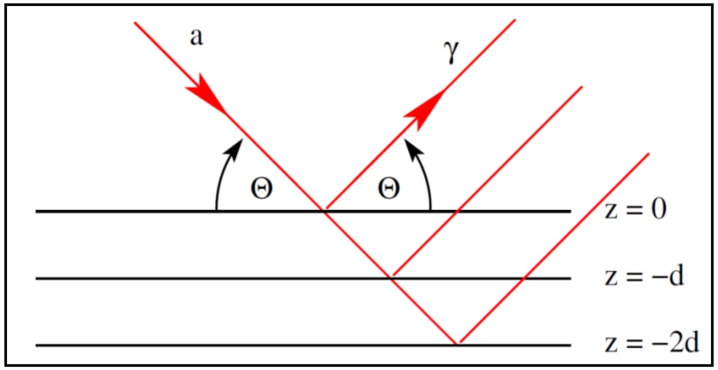
Production - detection



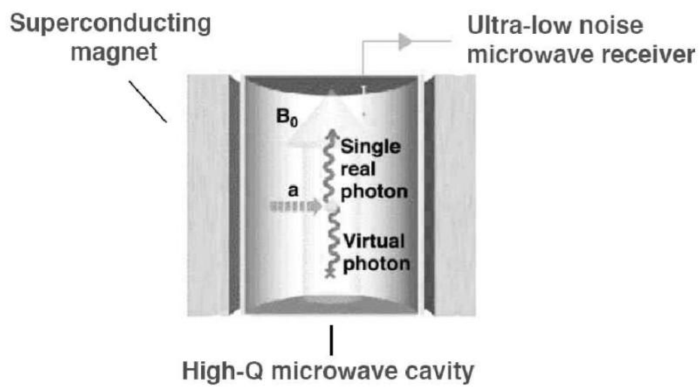


Direct Axion Detection Techniques (I)

Bragg Difraction



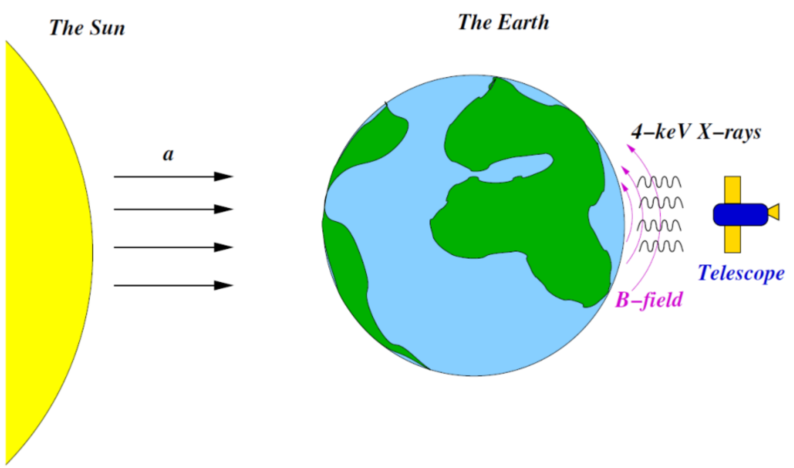
Microwave Cavity Searches



e.g. Asztalos et al., Phys. Rev. D 69, 011101(2004)

[astro-ph/0310042]

Geomagnetic Axion Conversion



Davoudiasl & Huber, hep-ph/0509293

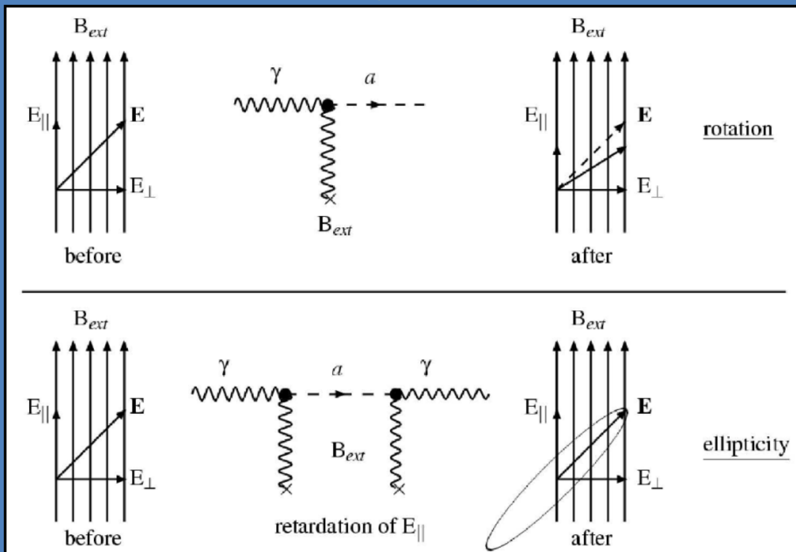
Axions can convert to photons in Earth's magnetic field

Idea is to observe the Sun through the Earth

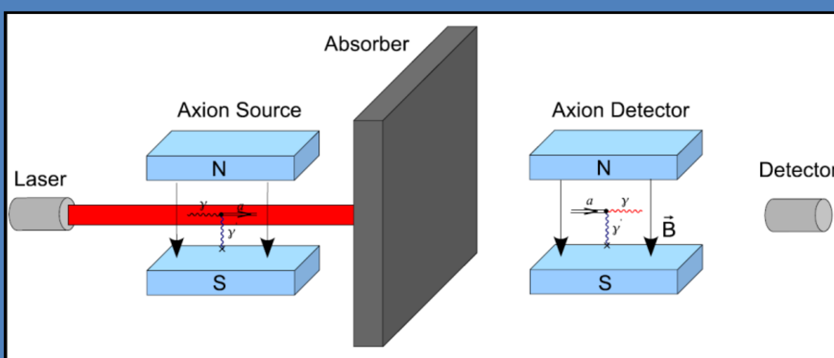
Direct Axion Detection Techniques (II)

Laser experiments

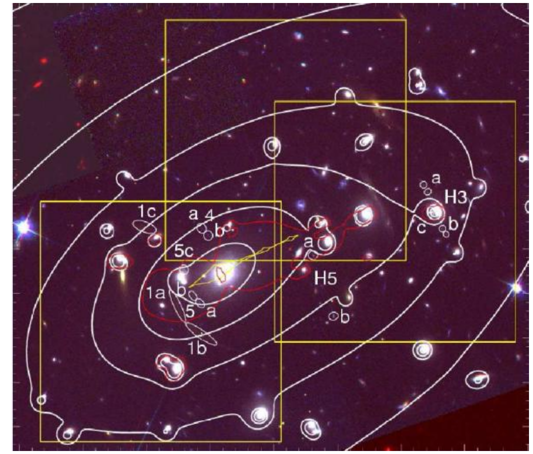
Vacuum properties



Light Shining Through Wall

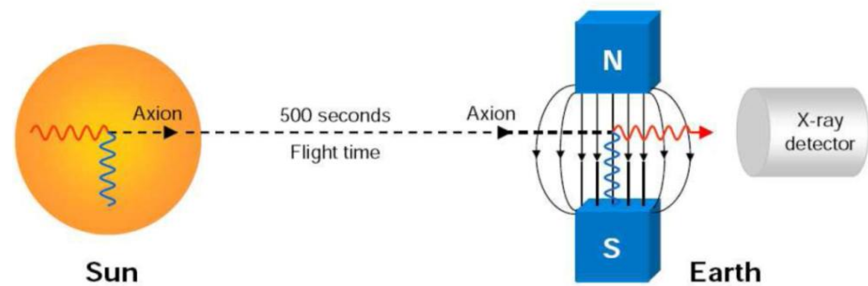


Telescope Searches



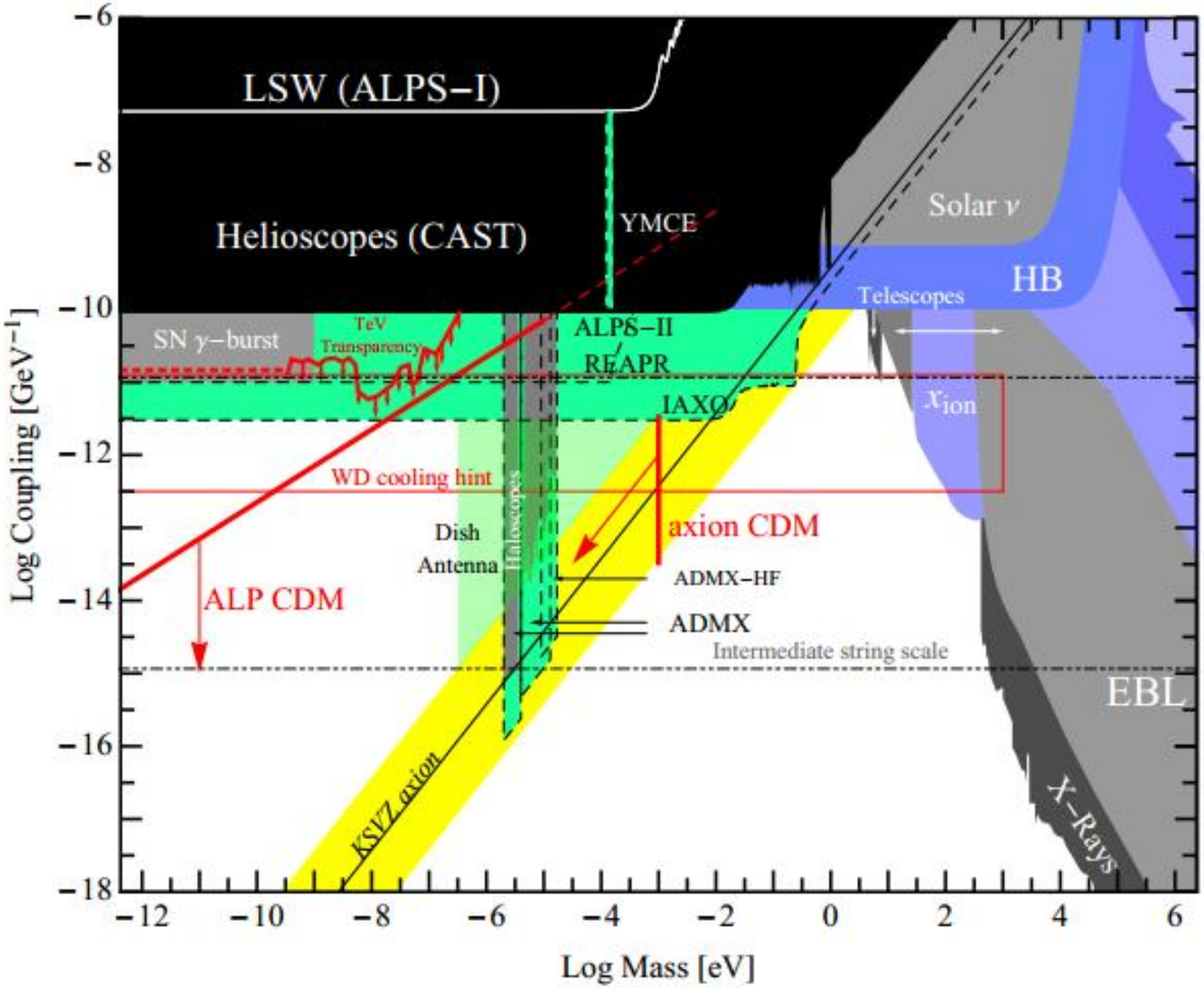
e.g. Grin et al. 2006 astro-ph/0611502v1

Helioscope Searches



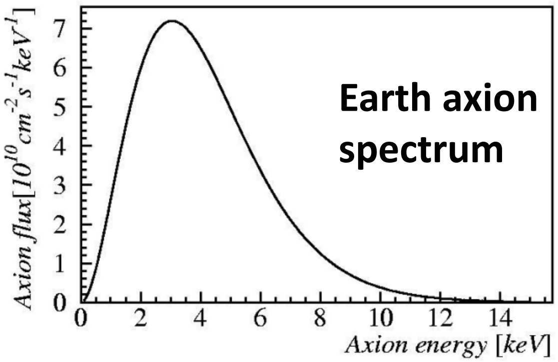
Inoue et al. 2002 astro-ph/0204388v1
Lazarus et al. Phys. Rev. Lett. 69 2333 (1992)

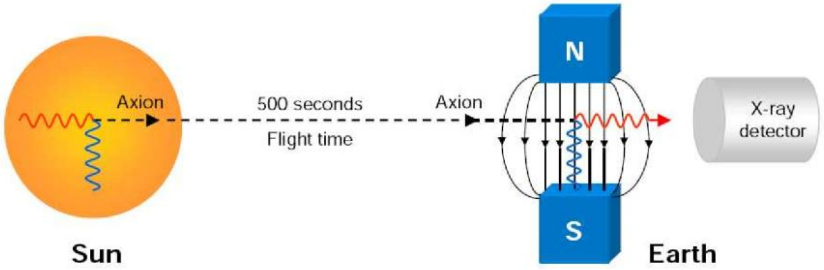
The axion search roadmap



The CERN Axion Solar Telescope (CAST) Experiment

Idea : Axions would be produced in the Sun's core and re-converted to x-rays inside an intense magnetic field. P. Sikivie, Phys. Rev. Lett. 51, 1415–1417 (1983)





CAST is using a prototype superconducting LHC dipole magnet able to track the Sun for about 1.5 hours during Sunrise and Sunset.
Operation at T=1.8 K, I=13,000A, B=9T, L=9.26m

Expected signal

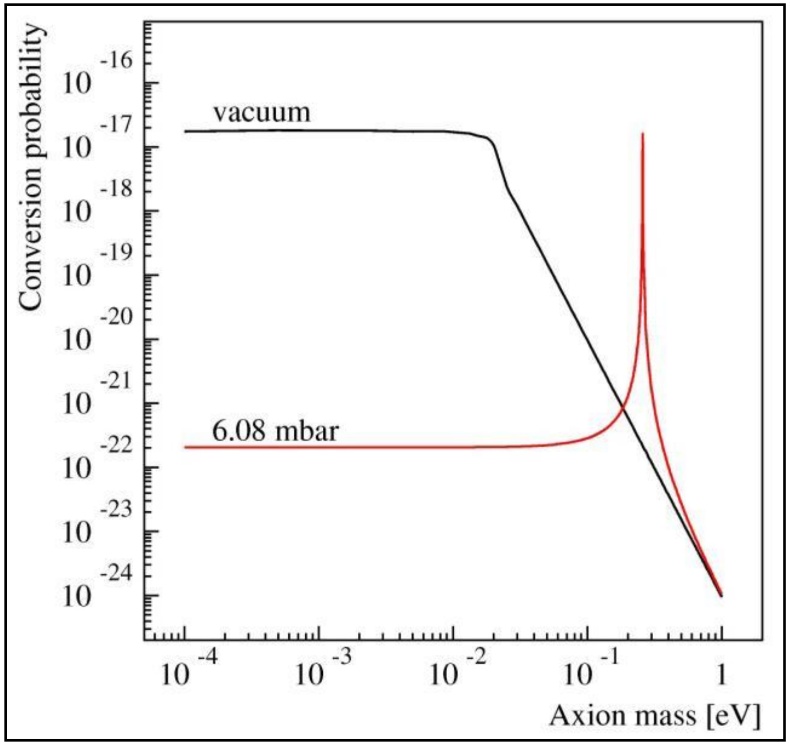
X-Ray excess during tracking at 1-10 keV region

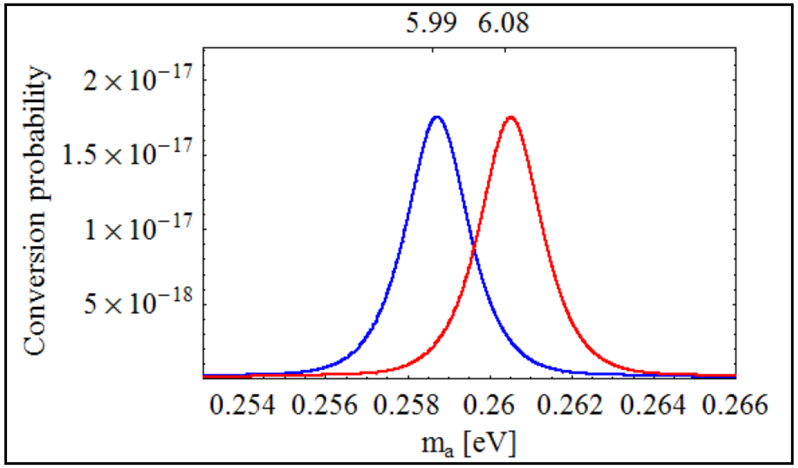
CAST sensitivity depends on the detector background

0.3 counts/hour in 14.5 cm^2

$g_{a\gamma\gamma} = 10^{-10}\ GeV^{-1}$

The CAST experiment : Axion mass scanning principle





$$P_{a\to\gamma} = \left(\frac{Bg_{a\gamma}}{2}\right)^2 \frac{1}{q^2+\Gamma^2/4}\left[1+e^{-\Gamma L/2}-2e^{-\Gamma L/2}\cos(qL)\right]$$

L = magnet lenght, Γ = absorption coefficient

$$q = \left|\frac{m_a^2 - m_\gamma^2}{2E}\right|$$

$$m_\gamma(eV) = \sqrt{\frac{4\pi\alpha N_e}{m_e}} \approx 28.9\sqrt{\frac{Z}{A}\rho} \approx \sqrt{0.02\cdot\frac{P(mbar)}{T(K)}}$$

<u>Expected Number of counts</u>

$$N_\gamma = \int \frac{d\Phi_a}{dE_a} P_{a\gamma} A_{CB}\, t_{tracking}\, dE_a$$

Assuming : $g_{a\gamma\gamma} = 1.0\,x10^{-10}\ GeV^{-1}$

$N_\gamma \approx 2$ events/day

The CAST experiment : Scientific results

CAST Phase I (Vacuum)

- ma<0.02eV
- **Completed(2003-2004)**
- PRL94(2005)121301
- JCAP04(2007)020

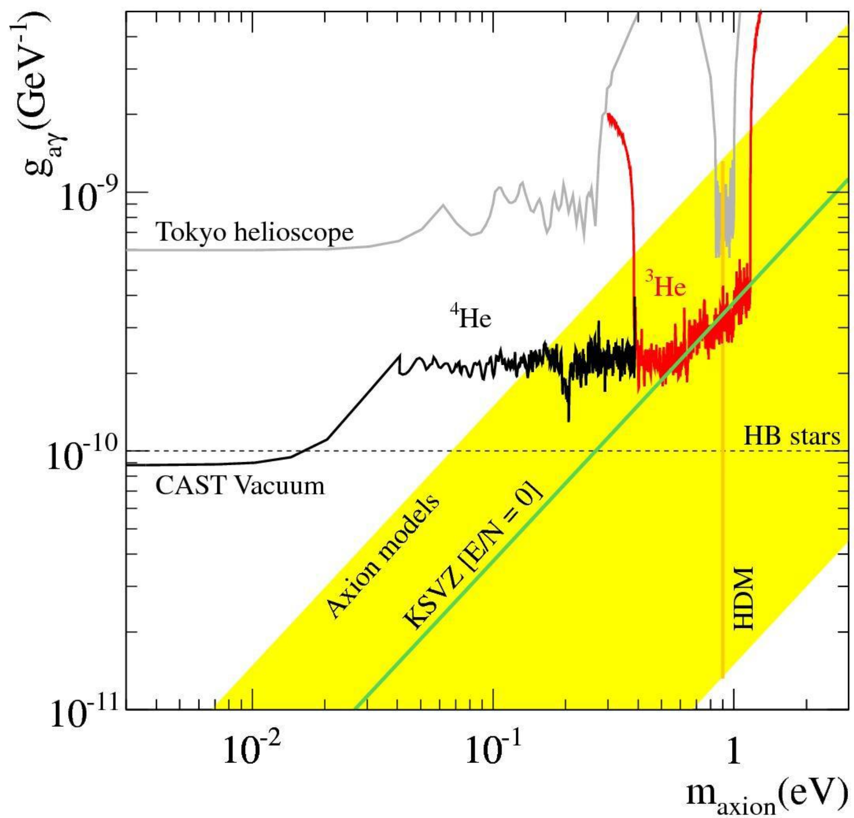
CAST Phase II (4He)

- P< 13.4mbar, 160steps
- 0.02<ma<0.39eV
- **Completed(2005-2006)**
- JCAP02(2009)008

CAST Phase II (3He)

- P< 120 mbar
- **Completed(2007-2011)**
- 0.39 < ma < 0.64 eV
Phys.Rev.Lett. 107 (2011) 261302
- 0.64 < ma < 1.15 eV
arXiv:1307.1985

Latest results up to 1.15 eV submitted for publication



The CAST experiment : Micromegas Detectors

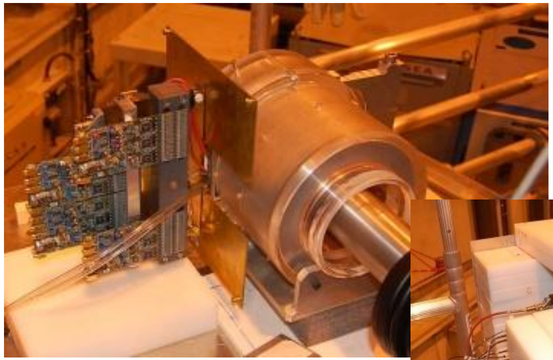
Remarkable improvement of Micromegas detectors inside CAST experiment.

3 Micromegas (Microbulk technology) installed in 3 of the 4 CAST magnet apertures.
Operating with Ar + 2% Isobutane at 1.45 bar

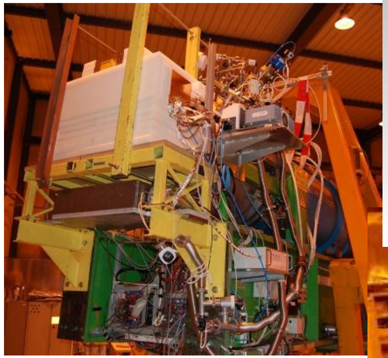
Readout 106x106 strips -> 6x6 cm2
Plus mesh temporal signal

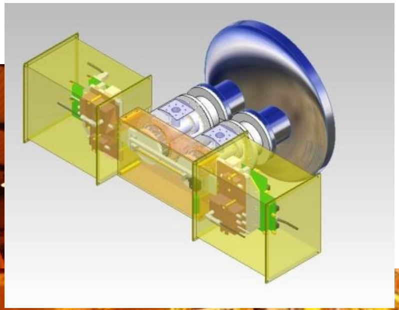
Detectors installation in 2008

Sunrise side detector



Sunset side detectors

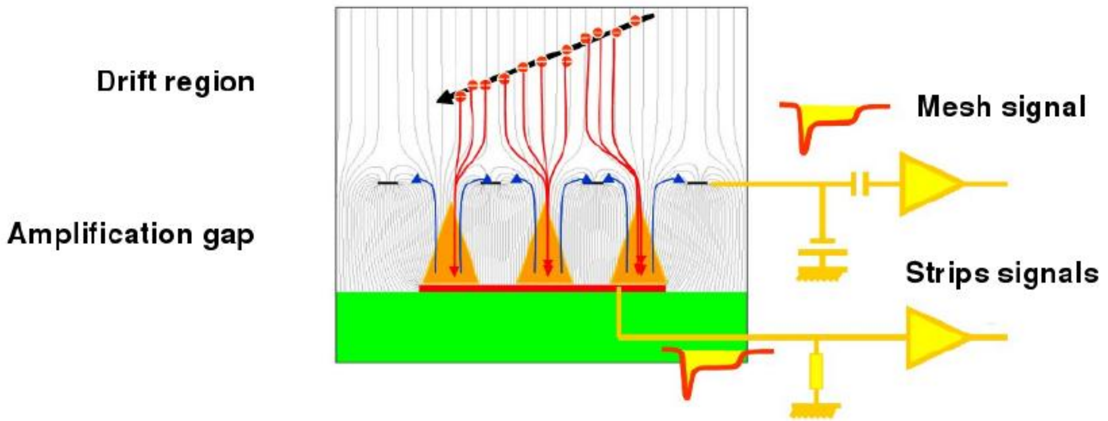


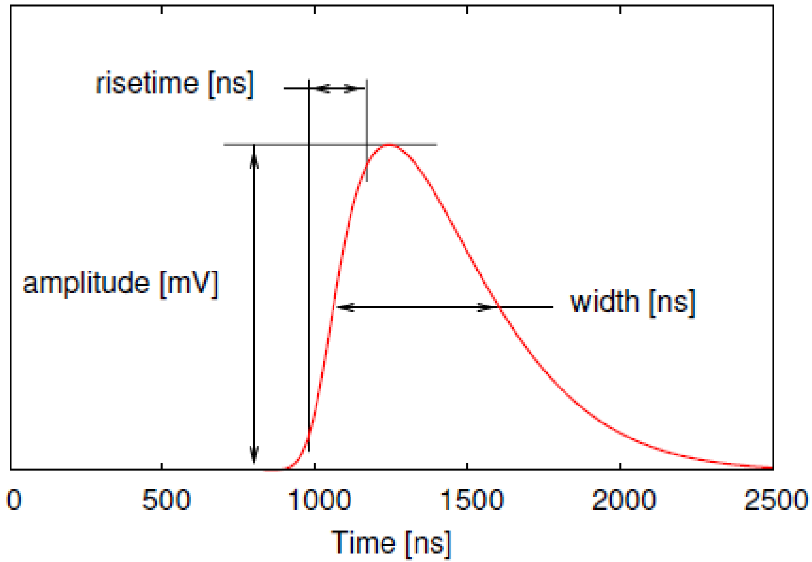


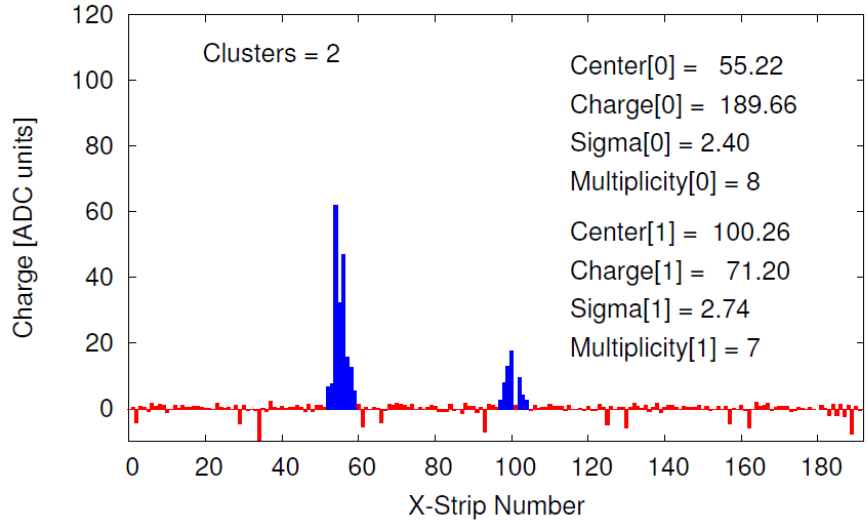
Micromegas : Detection principle and signal read-out.

CAST detectors readout provides **temporal and spatial information** of the events.

The temporal and spatial properties of events are to do an **efficient selection of X-rays.**



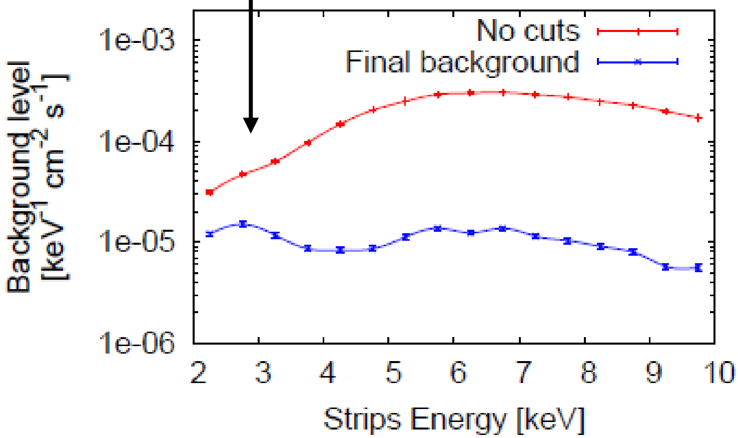


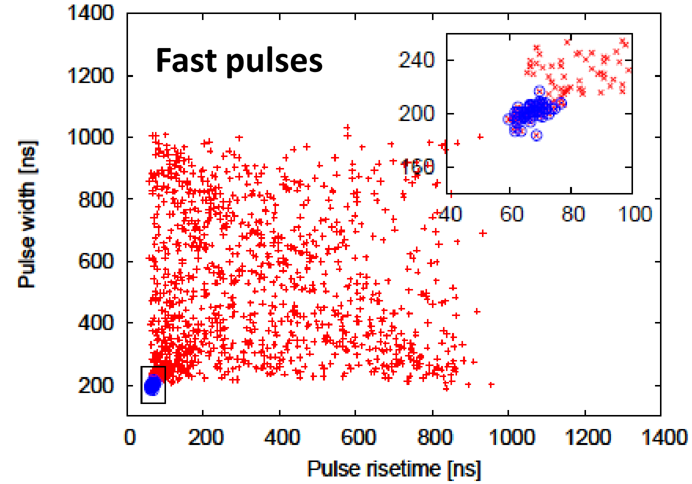


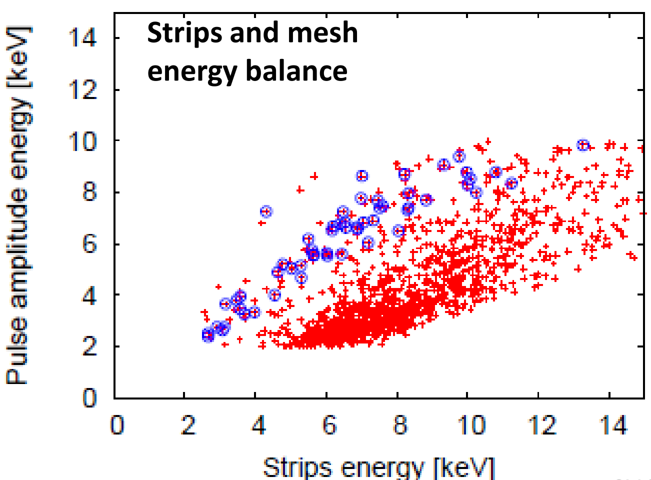
Micromegas : Background rejection capabilities.

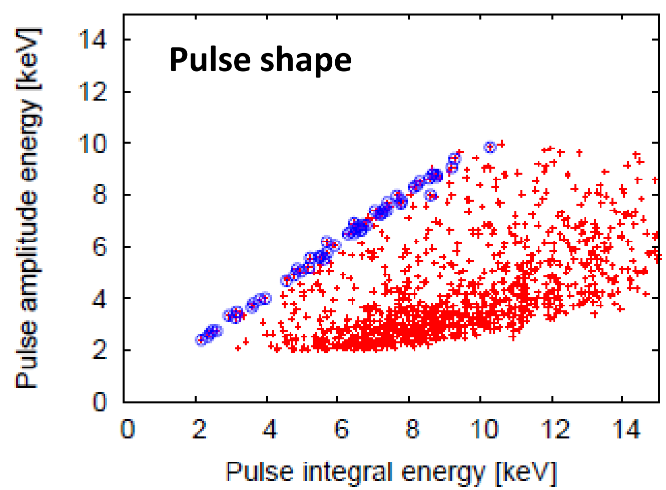
6keV events from an ^{55}Fe source are used for X-ray selection and background discrimination.

No cuts: Including only 1 xy-cluster events









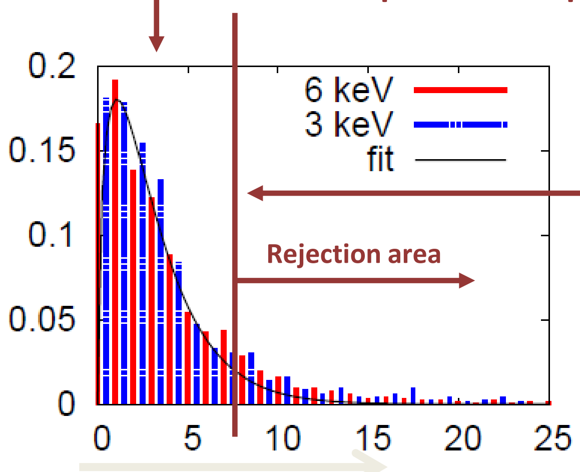
Micromegas : Multivariate analysis

Possibility to apply a multivariate analysis with the parameters obtained with the readout.

Pulse shape, risetime, cluster size, number of clusters

X-ray events coming from a X-ray Fe55 source are distributed around a ellipsoid centroid with a given distribution.

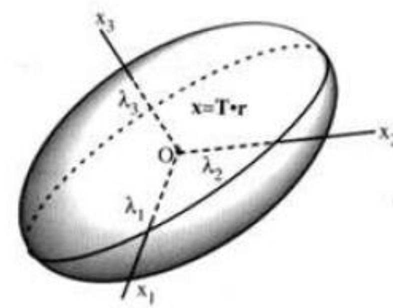
X-ray events are confined in a small volume at the parameter space.



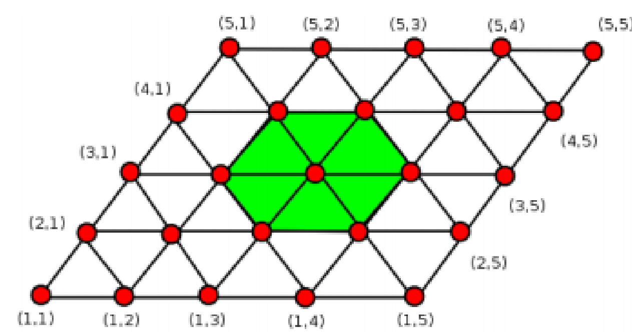
Multivariate distance

Software efficiency can be easily fixed by setting the distance limit.

Standard multivariate method



Topological (neural) network



Micromegas : Background rejection optimization

Good performance of Micromegas detectors during first years of operation at CAST. **Background could be reduced by improving detector technology and quality,** shielding and exploting discrimination capabilities.

Detector background depends on

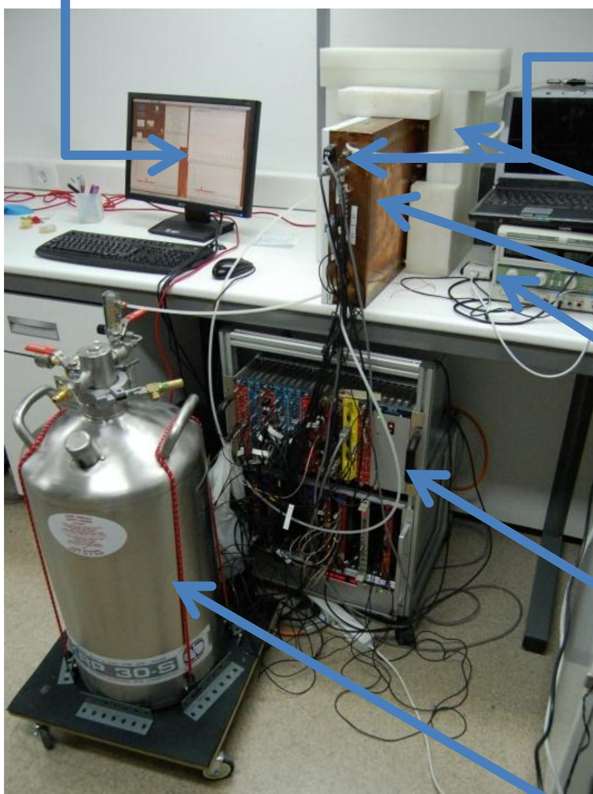
Intrinsic detector radiation
Micromegas detectors can be built with
low radiative materials (Plexiglass, Kapton, Copper)

Shielding from external radiation
Protecting the detector with material like
Lead, Copper, Polyethylene, Cadmium

Discrimination capabilities achieved by
New Micromegas technology. Detector stability and homogeneity.
Temporal and spatial event readout
Statistical offline analysis for optimized discrimination

Our group in Univ. Zaragoza (Spain) prepared further investigations to proof the background reduction limit achievable with these detectors.

A dedicated set-up at Zaragoza for background studies



New **acquisition software** completely based in C++, ROOT, python and GNUPLOT.

Gas, Ar + 2% iso, flowing in open loop with flow and pressure controlled

Shielding reproduces CAST configuration.

Faraday box prepared for **automatic calibrations** with ^{55}Fe source.

Slow control: temperature and pressure and detector currents

Some modifications in **electronics**. Fundamental modules are the same.

Nitrogen flux = 30 - 50 l/h (for vol < 17 l)
Capacity for more than 2 weeks.

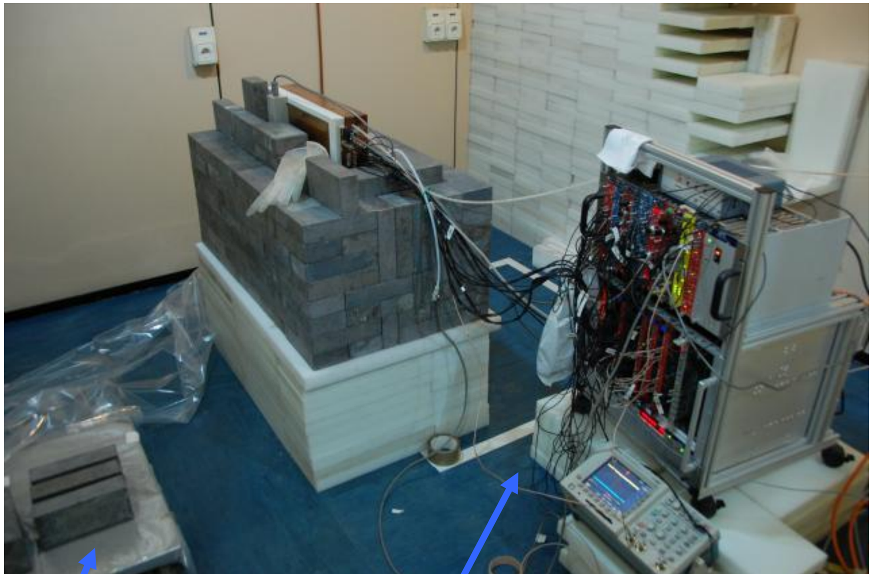
Background measurements at Canfranc Underground Laboratory

Canfranc Underground Lab (LSC) situated in the spanish Pyrenees at the deep of 2500 m.w.e

- 10^4 reduction factor in cosmic muons
- Stable environmental conditions (T, P, humidity)
- Environmental gamma radiation well known.

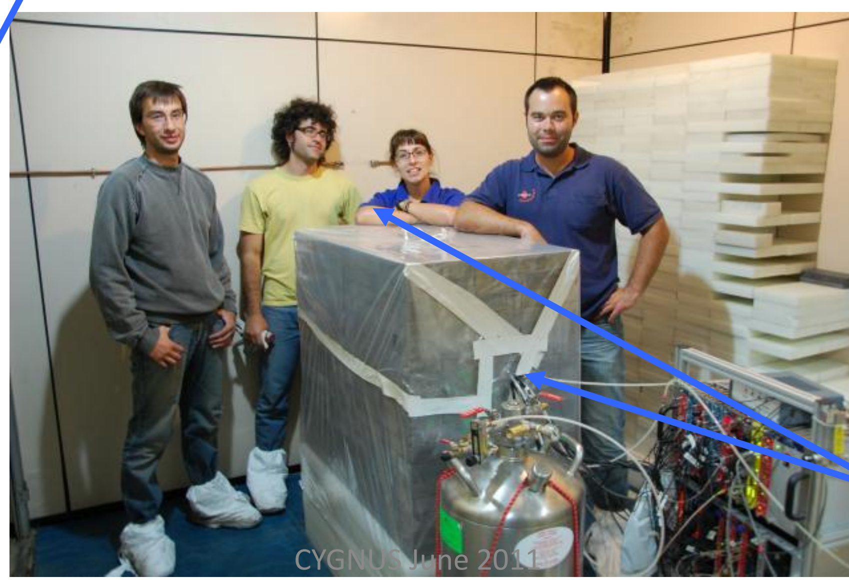
CAST-like set-up and shielding
Installed underground

Shielding upgrade to investigate intrinsic detector background



Bricks ready to be mounted.

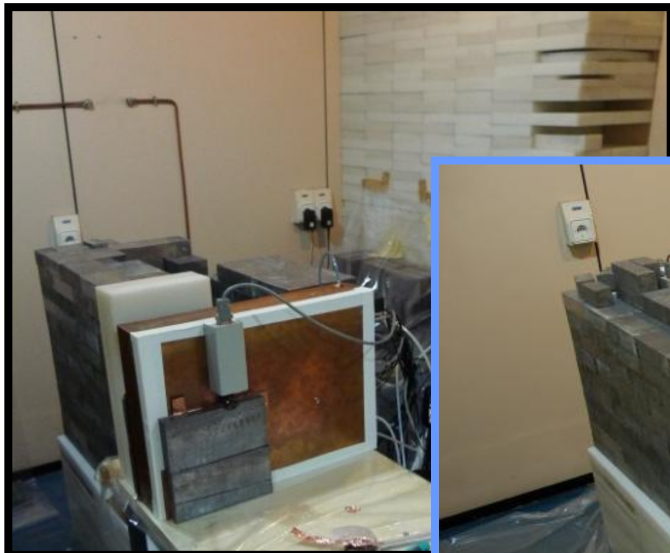
Crosschecking electronic noise and acquisition tuning



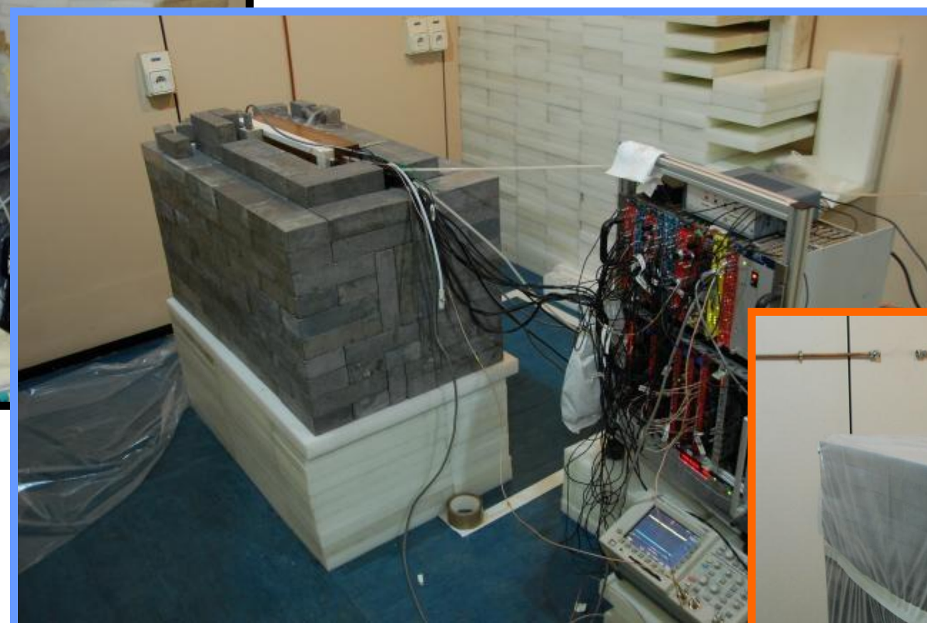
Small cabling passthrough hole

Some members of the crew proud of the new heavy gift just installed.

Data taken at 3 different shielding configurations



CAST-like:
No external Pb
(but still 4π)

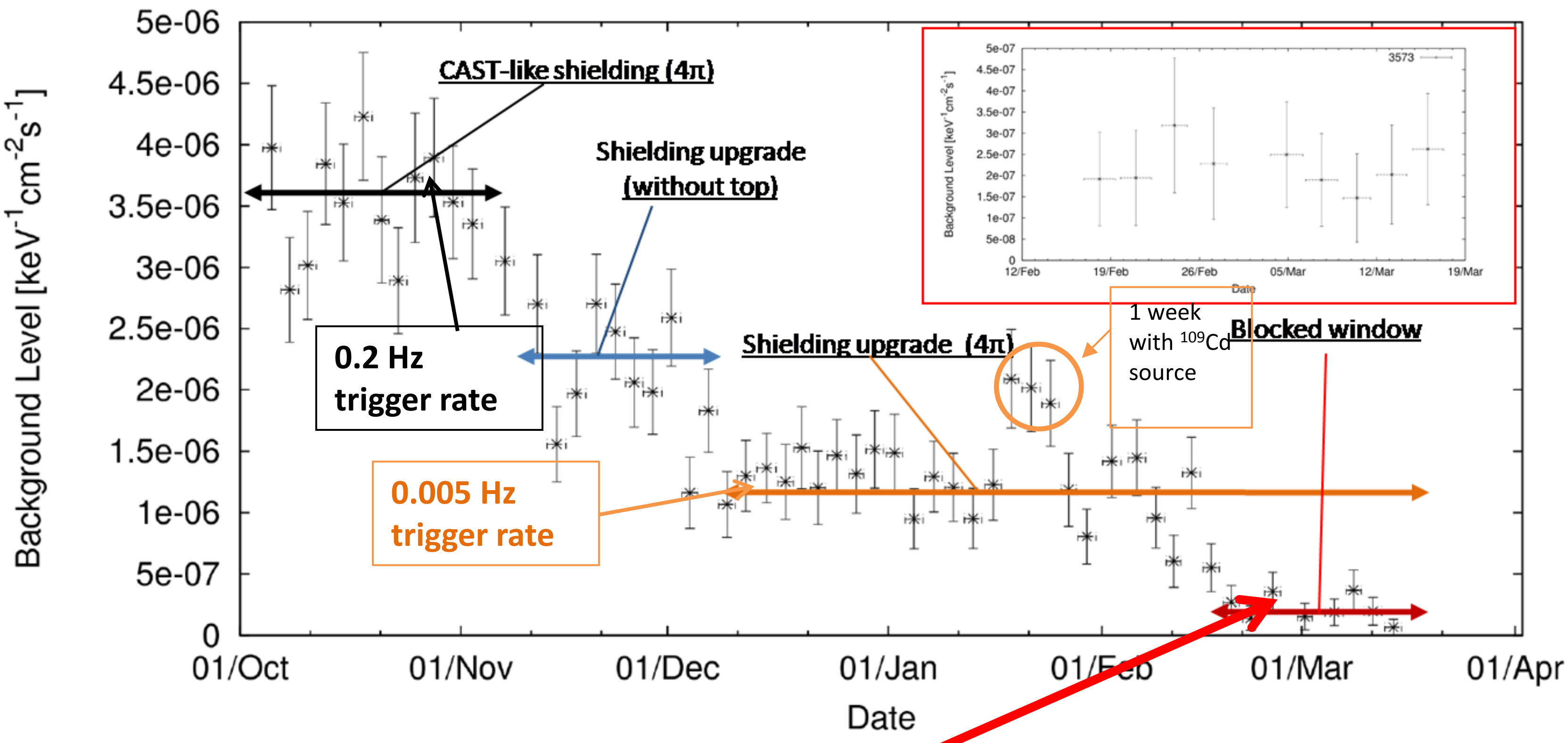


"Half" closed:
5π/6 20 cm external Pb

Complete:
20 cm
external Pb

0,5 cm Cu + 2,5 cm Pb
+ Nitrogen flux to avoid Rn

Data taken at 3 different shielding configurations



First approach to final background limited only by intrinsic radioactivity (from microbulk, chamber materials, inner shielding):

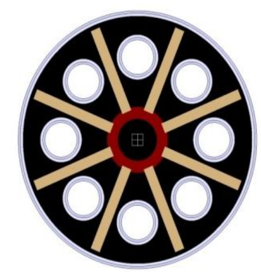
< $2\cdot10^{-7}$ counts keV^{-1} cm^{-2} s^{-1} [2-7 keV] (~1 count/day)

This result proves that background levels >20 times lower that current CAST MM nominal background are possible via shielding improvement.

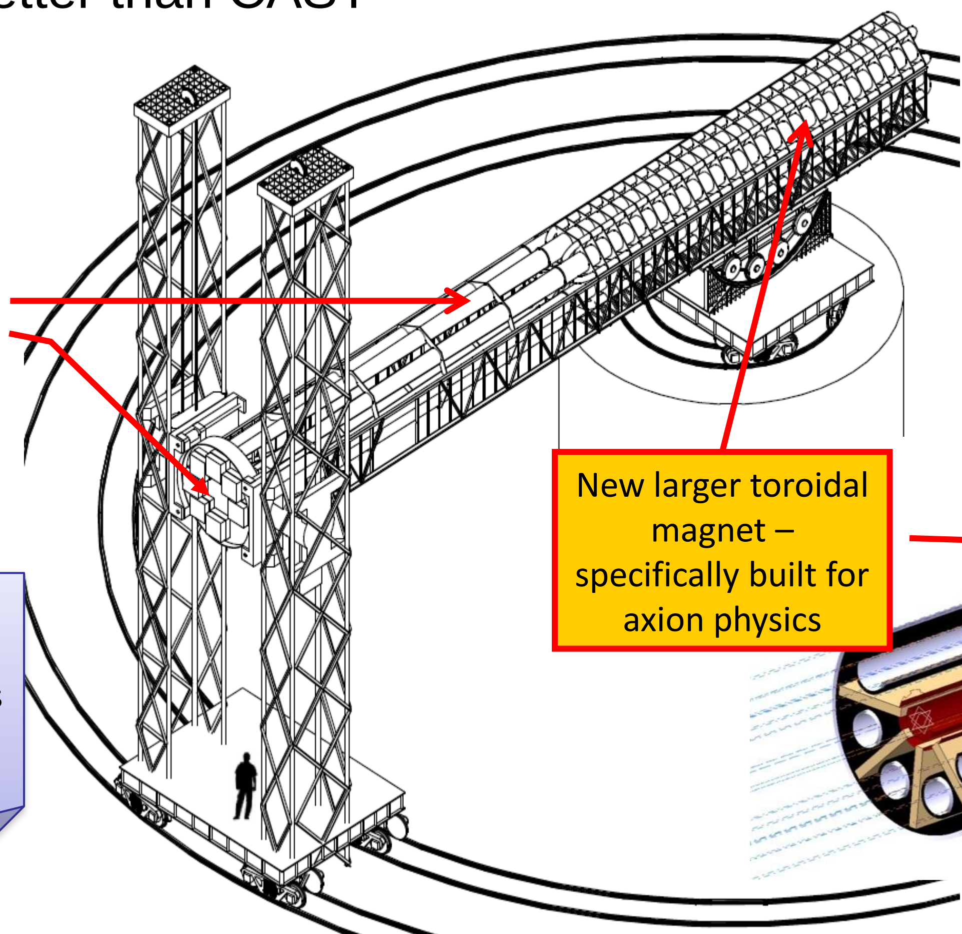
International AXion Observatory (IAXO)

- Towards a new generation axion helioscope
- Conceptual Design Report and **Letter of Intent** to CERN in preparation.
- **Goal**: 1-1.5 orders of magnitude in sensitivity to $g_{a\gamma}$ better than CAST

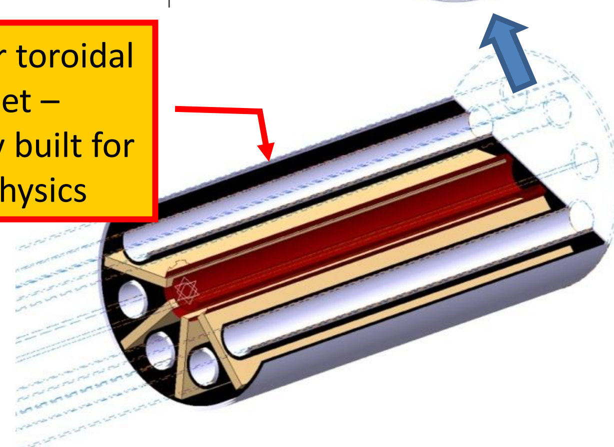
Each conversion bore (between coils) about 0.5-1 m diameter



All bores equiped with x-ray focusing and low bkg detectors
-
Fully exploiting innovations of CAST

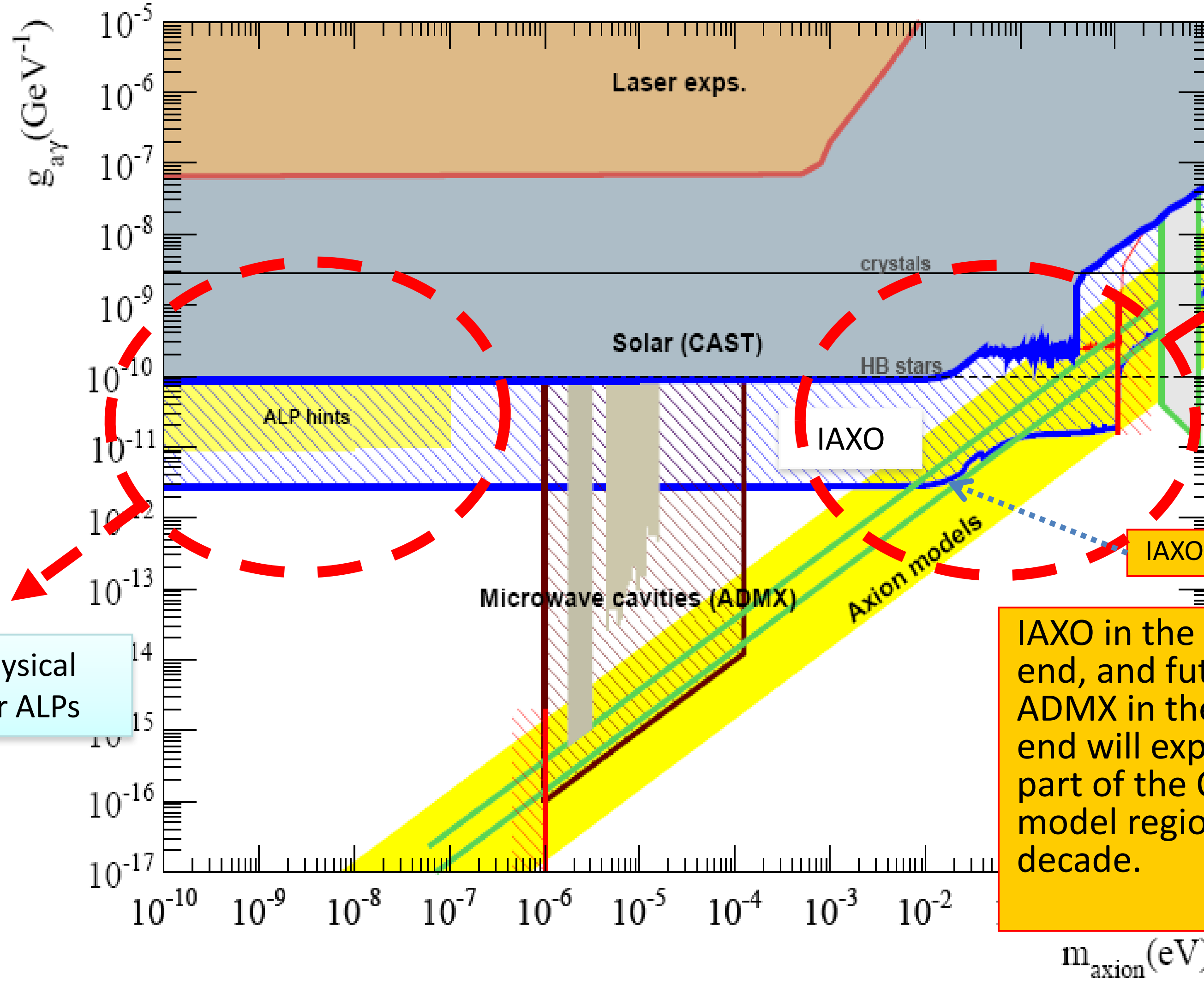


New larger toroidal magnet – specifically built for axion physics



First feasibility results and sensitivity prospects recently published: *JCAP 1106:013,2011 (arxiv:1103.5334)*

IAXO sensitivity prospects



Much larger QCD axion region explored

Astrophysical hints for ALPs

IAXO prospects

IAXO in the high mass end, and future phases of ADMX in the low mass end will explore large part of the QCD axion model region in the next decade.

Micromegas technologies

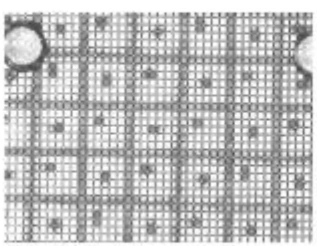
In first Micromegas detectors (conventional technology) mesh and read-out strips were two independent entities. **New technologies were developed to keep mesh and strips in a single entity** providing a fixed amplification gap.

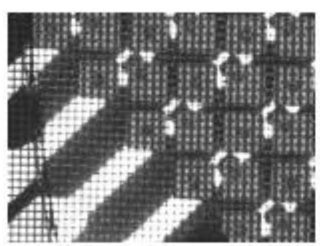
Bulk

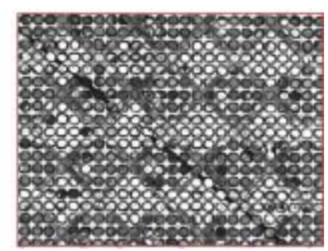
30 um inox mesh
128 um pillars
Reacheable energy resolution 18% FWHM @ 6 keV
Spatial uniformity and very robust
Limit on energy resolution due to thickness of the mesh

Microbulk

5 um copper mesh
30 um mesh holes
Pillars are replaced by attached Kapton substrate.
Reacheable energy resolution (<13% FWHM @ 6keV)
Good behaviour against sparks







Microbulk micromegas fabrication process

Kapton foil (50μm), both sides Cu-coated (5μm)

Construction of readout (strips/pads)

Added a single-side Cu-coated kapton foil (25/5)

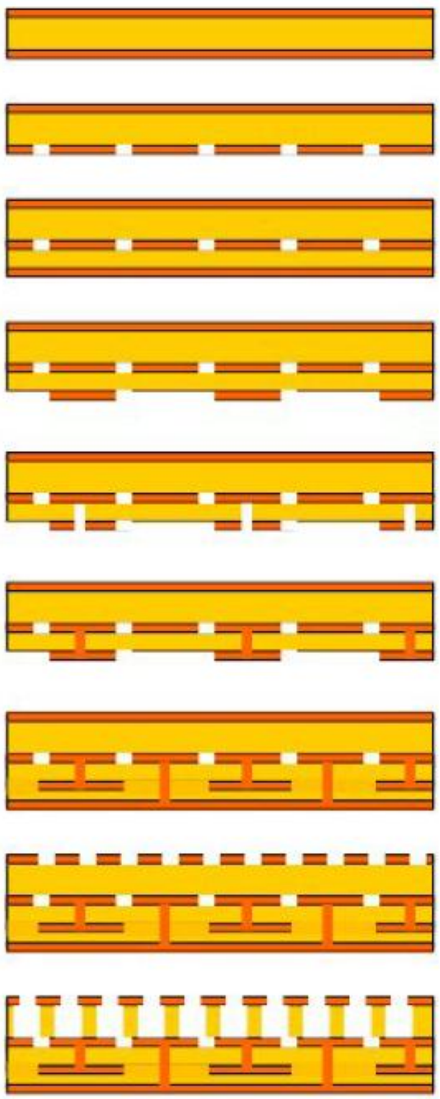
Construction of one direction
readout lines

Vias construction by
etching the kapton

Construction of the second
direct readout lines and vias

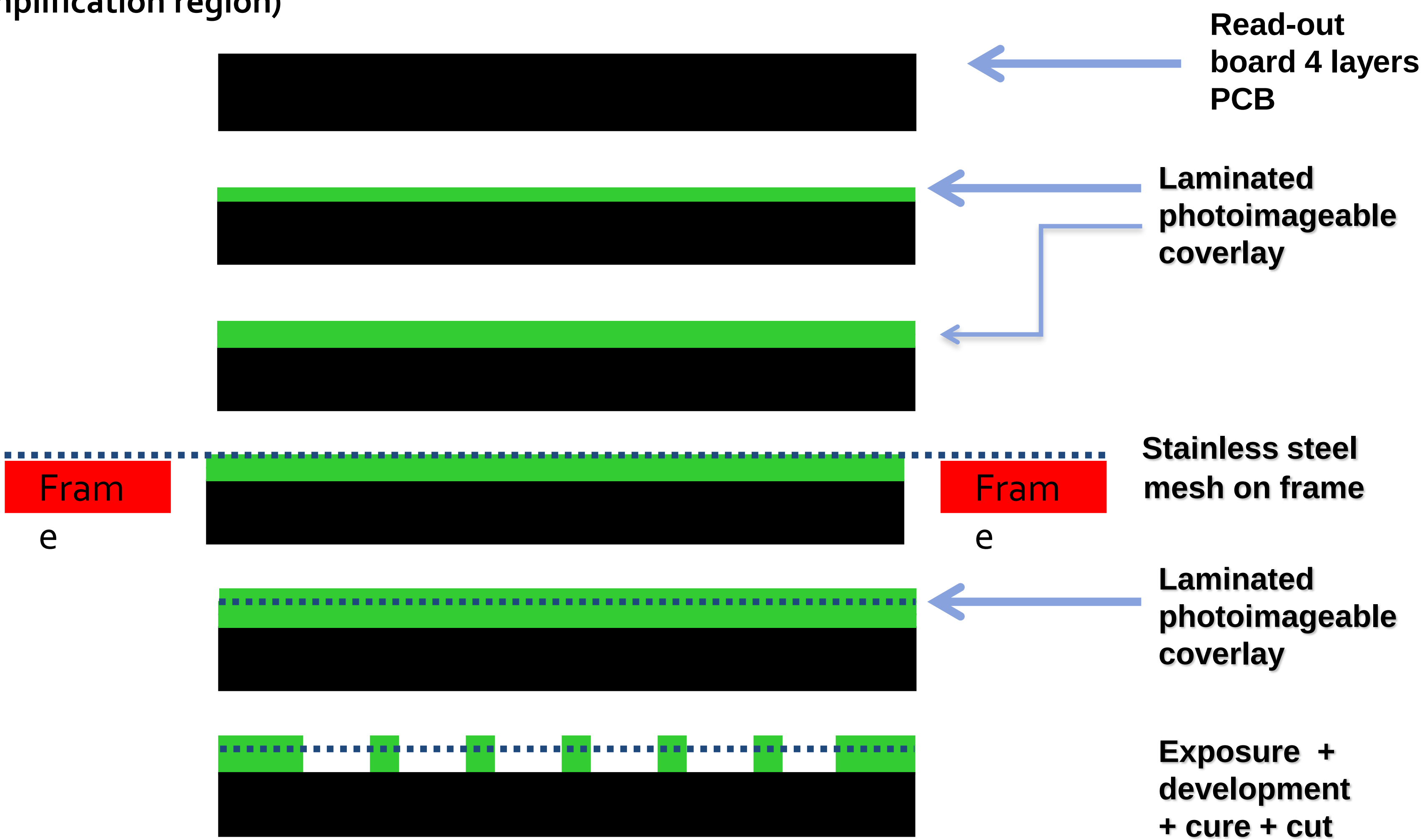
Photochemical production of mesh holes

Kapton etching and cleaning



Bulk micromegas fabrication process

The micro mesh consist of 18um µm thick stainless steel 400 Lpi woven microstrings. This micro mesh is embedded between two photoimageable coverlay layers with a micron precision (to define the amplification region)



Easy manufacturing - Large size compatible - Low cost
Robust and electrically testable at the production time

I. Giomataris et al, NIM A560 (2006) 405

New resistive micromegas technologies

Micromegas started to use ressitive coatings to reduce the discharge weakness of Non-resistive Micromegas.

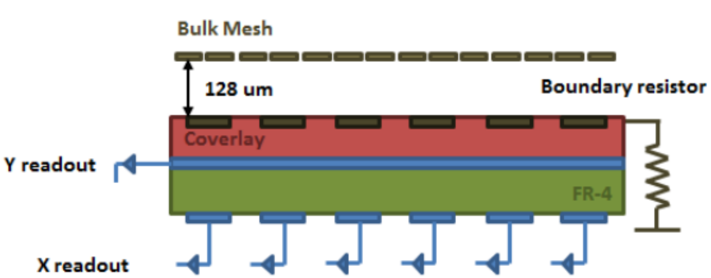
Discharges in general have a negative effect on the detector by

- Increasing the dead time of the detector (field loss during few ms due to charge loss recovery time)
- Damaging the electronics due to the high intensity currents.
- Damaging the detector itself by melting electrodes.

Resistive bulk

An insulating layer is placed on top read-out strips, then high resistive strips are placed on top.

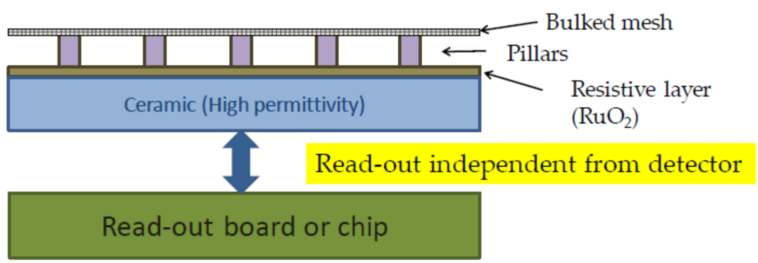
Also for large area applications



Piggyback (ceramic-resistive micromegas)

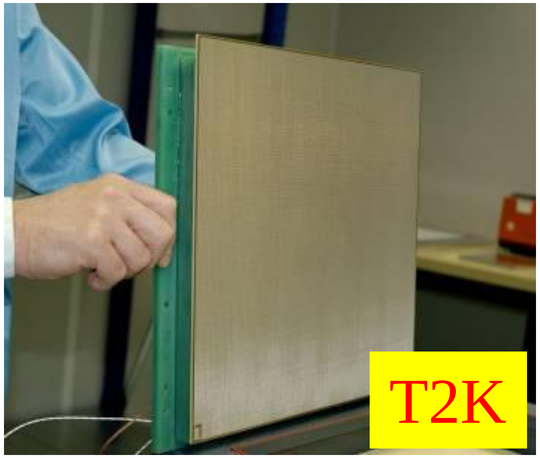
Micromegas are bulk-ed in a ceramic substrate with a resistive coating.

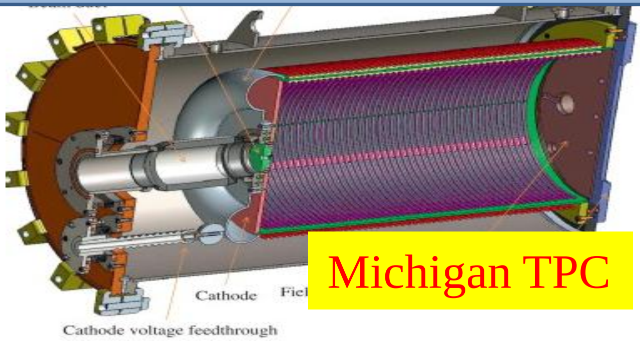
Read-out independent from detector.

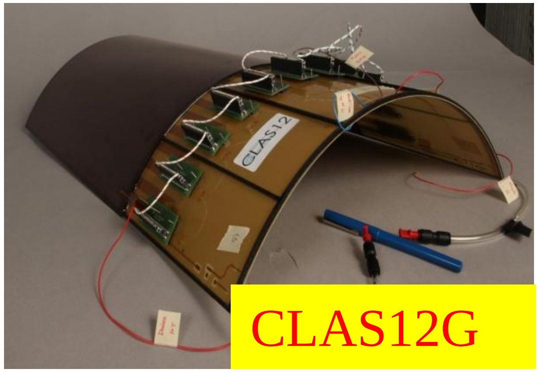


Signal transmission through capacitive coupling, high ceramic permittivity

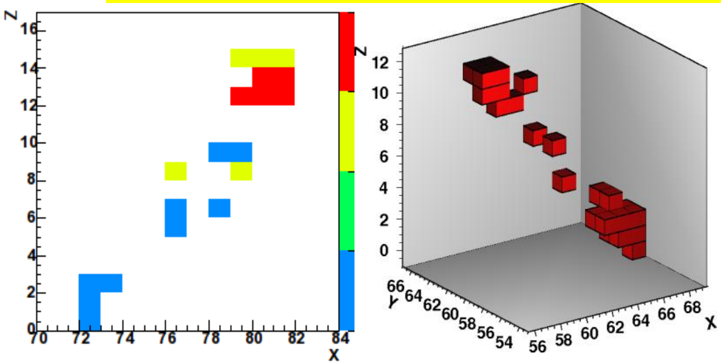
Micromegas in other experiments

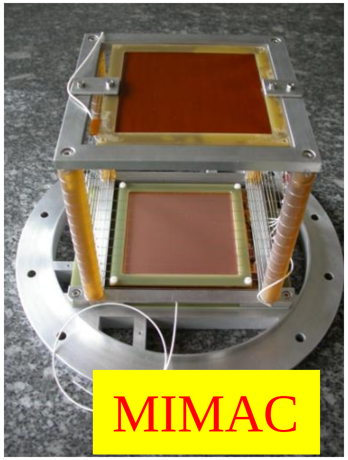




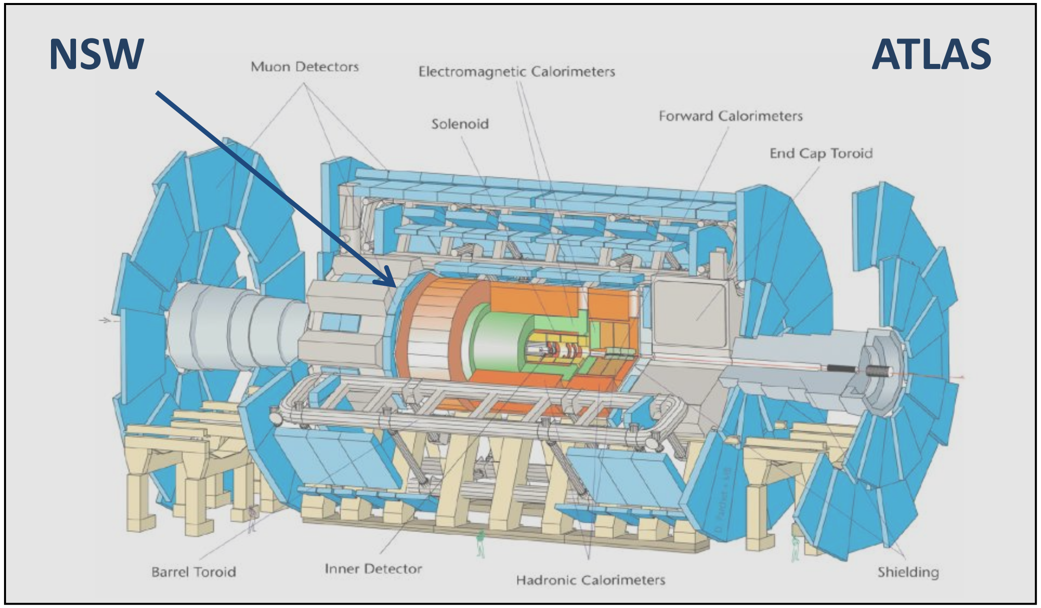


6 keV electrons in He + 5% iC_4H_{10} 350 mbar





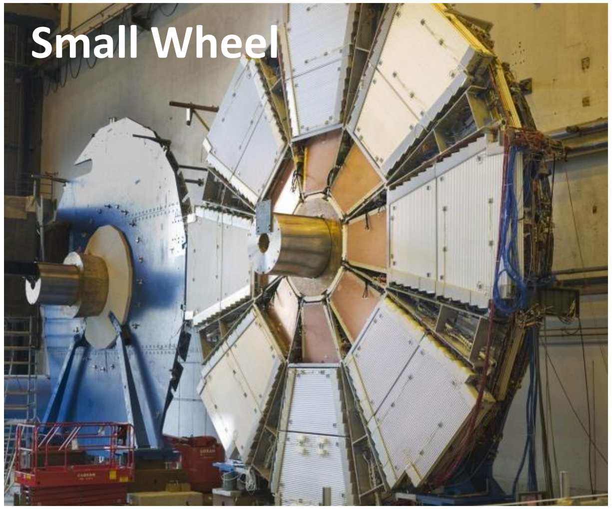
The New Small Wheel upgrade for the HL-LHC



Performance requirements

- Rate capability: 10 kHz/cm^2 ✓
- Spatial resolution: 60 µm/track segment ✓
- Angular resolution: 0.3 mrad/segment ✓
- Good double track resolution ✓
- Trigger capability: BCID (angle ≈ 1 mrad) ✓
- Efficiency: 'at least as good as now' ✓
- Radiation resistance: tbd (✓)
- Good ageing properties: tbd (✓)

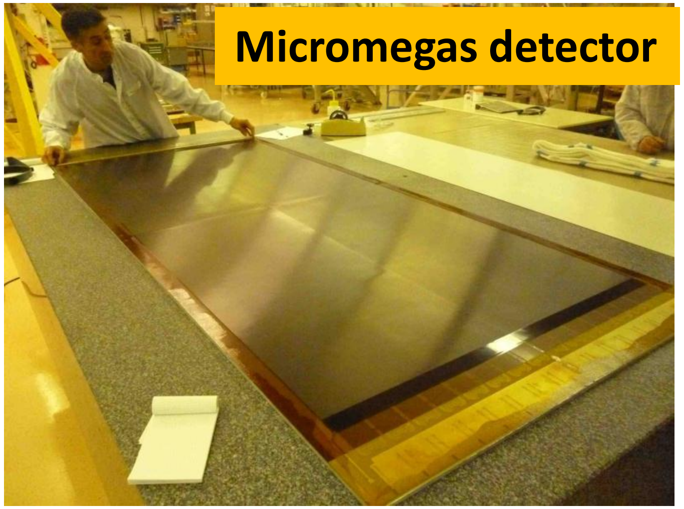
NSW meeting, 06/10/2011 Joerg Wotschack (CERN) 11



Total area of micromegas detectors required

1200m^2

Large area due to multilayer micromegas will be implemented in each sector.

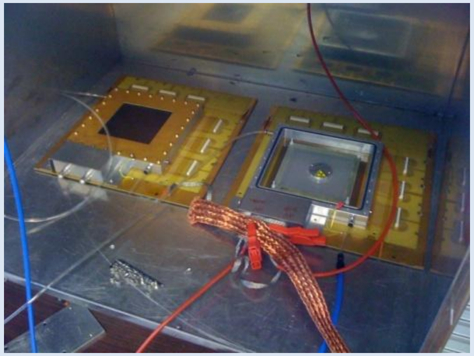


Ressitive Micromegas Ageing tests

X-ray beam

Cold neutron beam

Alpha source



Gamma source

A resistive prototype detector is exposed to different radiation natures.

Gain control measurements are performed before and after each exposure.

After the ageing both detectors are taken to the **H6 CERN-SPS pion beam line.**

The goal **to accumulate an integrated operation charge equivalent to the one would be obtained at the HL-LHC for 10 years for each type of radiation.**

Neutron irradiation: Orphee reactor

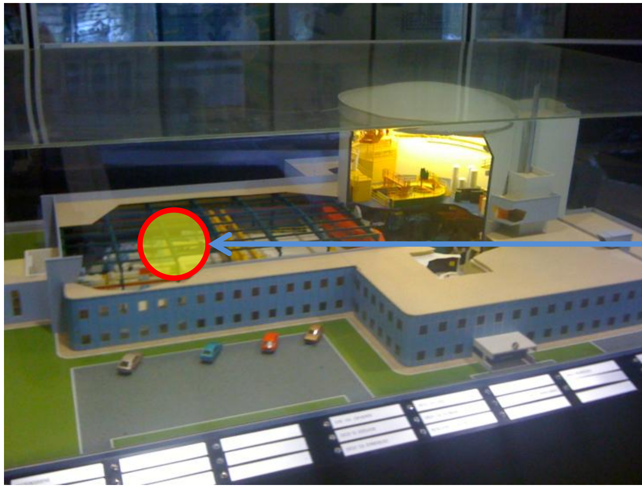
High intensity thermal neutron irradiation had place at C.E.A. Orphee reactor.

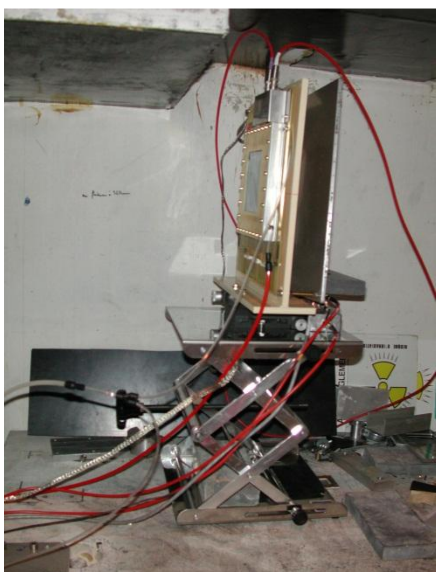
Several neutron research lines available.

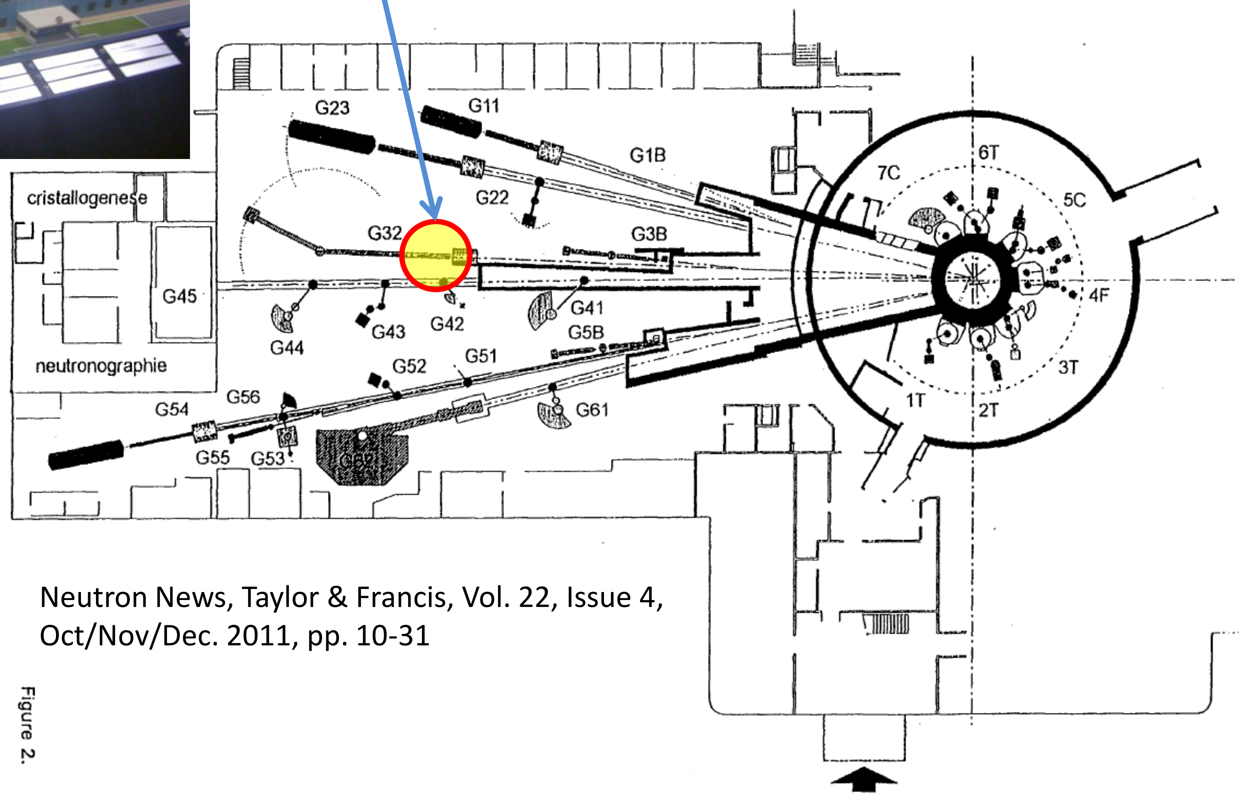
Neutron flux : ~8.10^{8} n/cm2/sec

Neutron energy : 5 to 10 meV

Detector emplacement at Orphee reactor Neutron guide



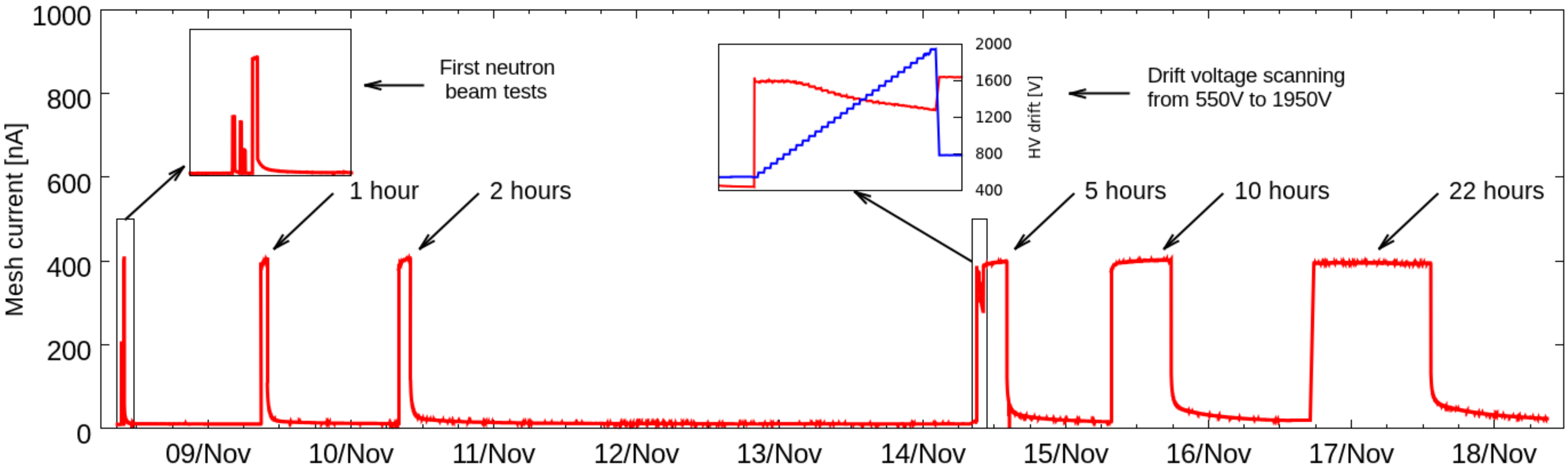




Neutron News, Taylor & Francis, Vol. 22, Issue 4, Oct/Nov/Dec. 2011, pp. 10-31

Figure 2.

Neutron irradiation: Mesh current history

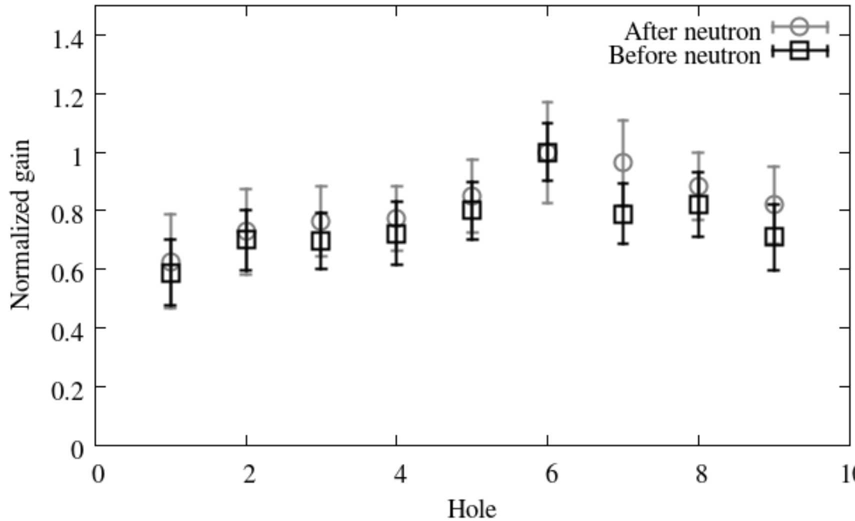


Neutron flux at the level of CSC in ATLAS ~3.10^4 neutrons/cm2/s

10 years at HL-LHC (=> x10.10^7 sec) with a security factor : x3

At the HL-LHC, we will accumulate 1,5.10^{13} n/cm2

At Orphee we have ~8.10^8 n/cm2/sec so in 1 hour we have : 8.10^8 x 3600 ~ 3.10^{12} n/cm2/hour which is about 2 HL-LHC years (200 days year).



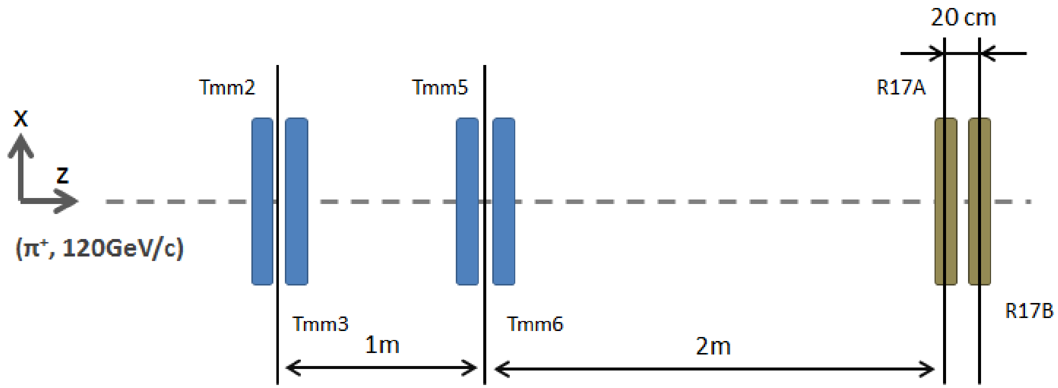
Pion beam measurements after ageing

The two R17 prototypes were taken to the H6 SPS CERN pion beam to perform a **comparative study between both prototypes**, **irradiated** and **non-irradiated** one.

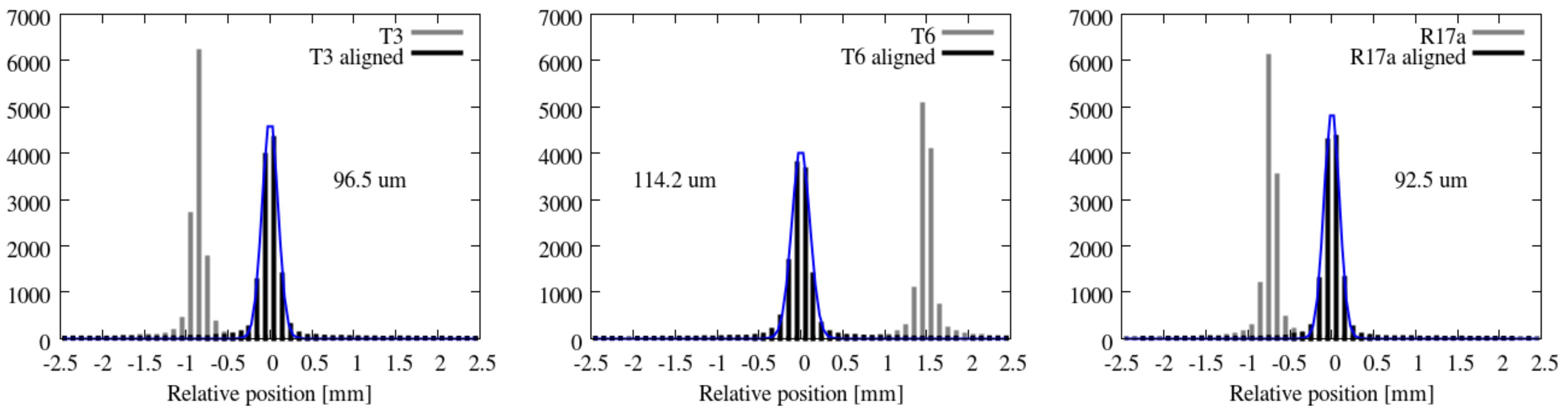
The performance was evaluated in terms of spatial resolution (SR) and efficiency.

Simplified beam set-up with R17 detectors

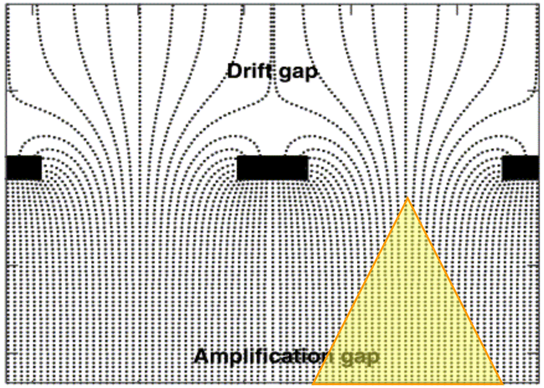
Detectors long offset produces systematics due to pion scattering. Resistive detectors were considered for track reconstruction. Non final set-up for intrinsic SR determination.



Residual distribution and alignment of resistive R17 prototypes to reference chambers

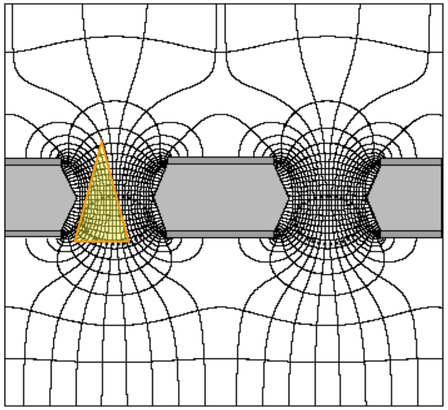


A low energy threshold detector. Spherical Geometry.

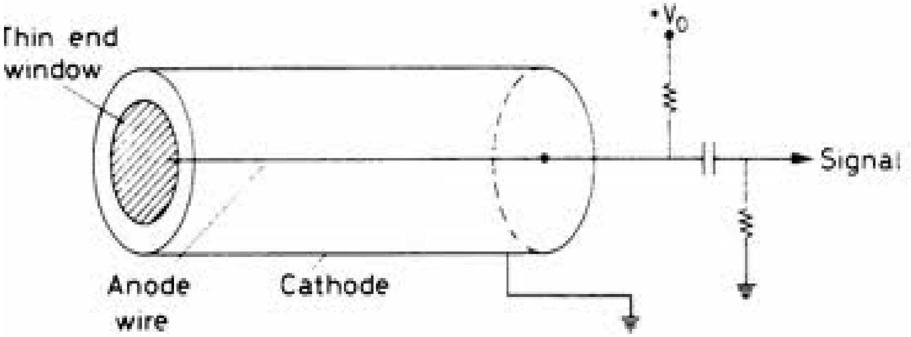


Micromegas

E= constant
$C \approx S > 1nF$

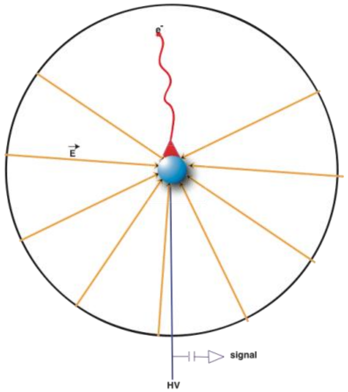


GEM



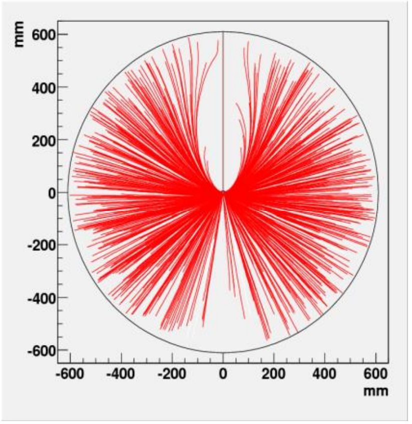
Cylindrical Proportional Counter

$E=V/\ln(b/a)r$ L = length and
a=radius of the wire, b = tube radius
$C = 2\pi L/\ln(b/a) >> 10$ pF



Spherical Proportional Counter

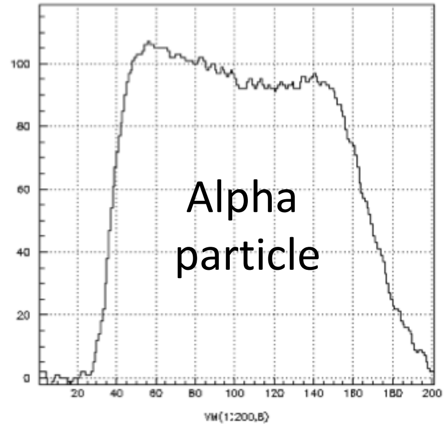
$E=1/r^2$
$\approx V/R_i$ close to the ball
$C \approx R_{in} < 1$pF

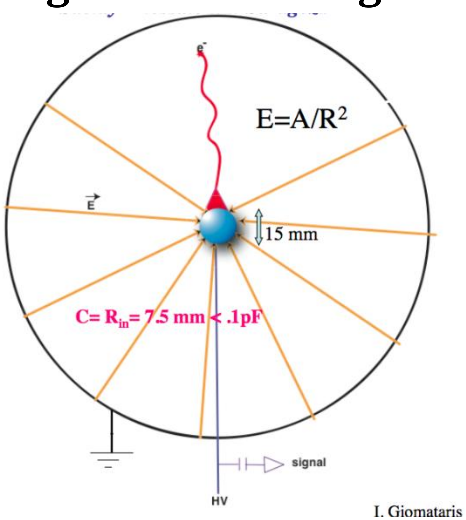


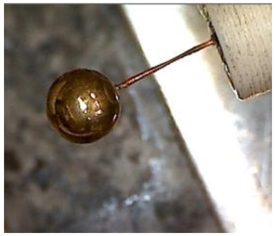
Spherical TPC advantages

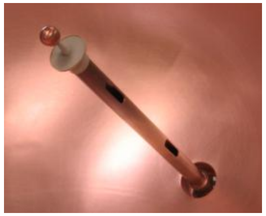
- Simple and cheap
- Large volume
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut
- High dinamic range

Good capability for particle recognition









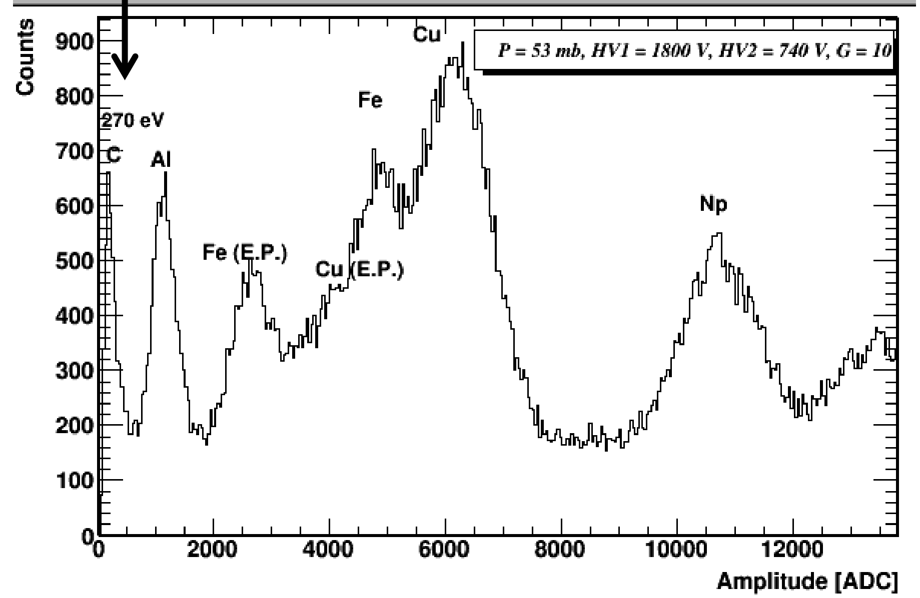
A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008

Great flexibility (P, gaz)
Allows to play with parameters used for discrimination and background

Long drift times (few hundred of microseconds).
Fiducial selection by risetime

World record with TPC (C peak @270eV)

Am241 source with polypropylene foil

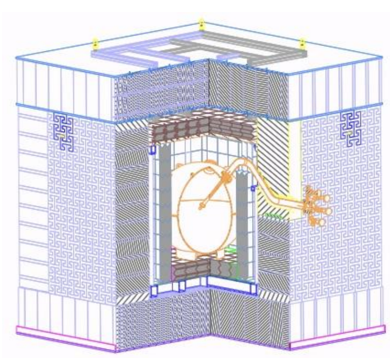


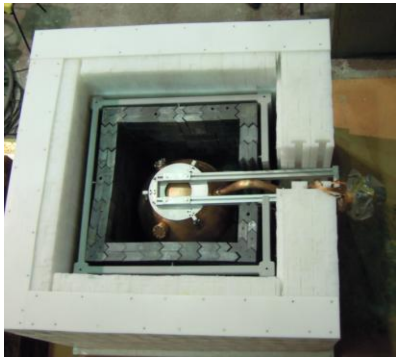
Detector set-up and calibration

Existing spheres running in ground and undergraound laboratories

2 LEP cavity 130 cm Ø
1 low activity 60 cm Ø in operation @ LSM

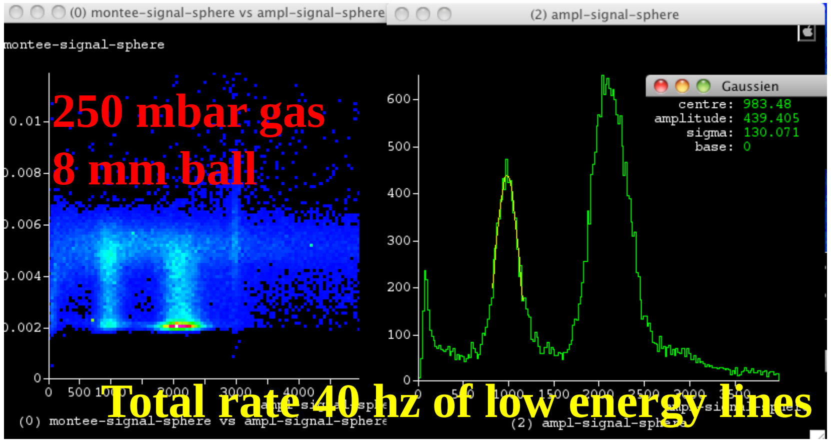
SEDINE set-up at Modane (LSM) 30 cm sphere
Underground
Radiopure copper sphere
10-15 cm lead
25 cm poliethilene
Purified air (Radon free)



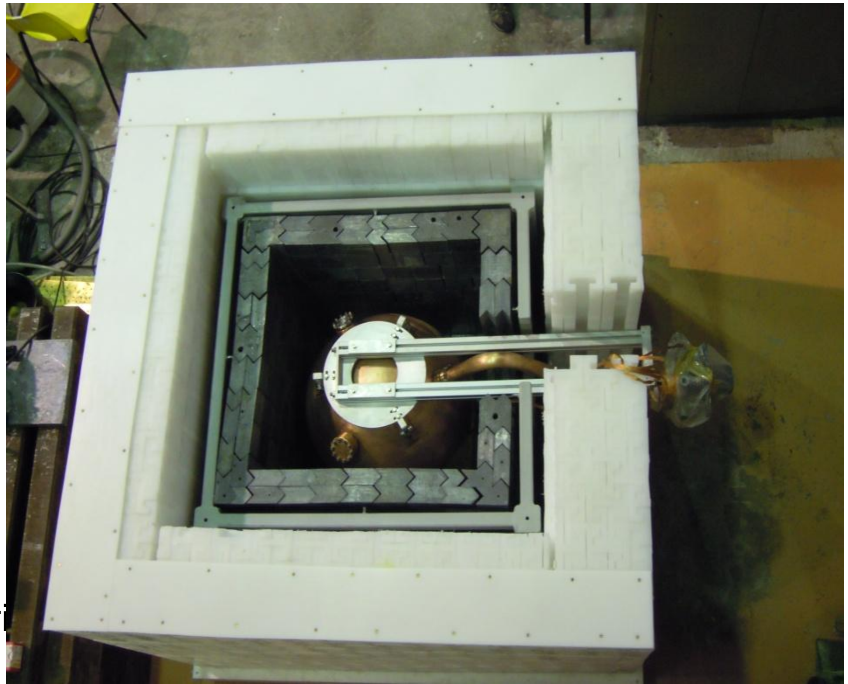


Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons 7×10^6neutrons/s

Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d



Detector construction and installation at LSM (France)

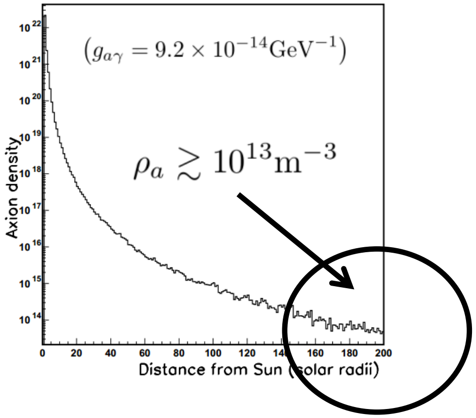


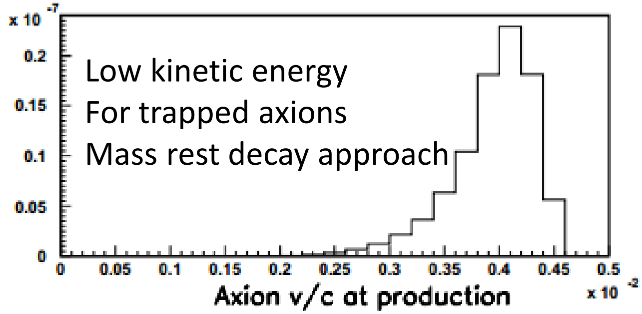
Motivation and sensitivity to KK-axions

Gravitationally trapped massive Axion (like) particles decays

L. Di Lella, K. Zioutas, Astropart. Phys. 19 (2003) 145

$$T_\odot \ll \tau_a$$





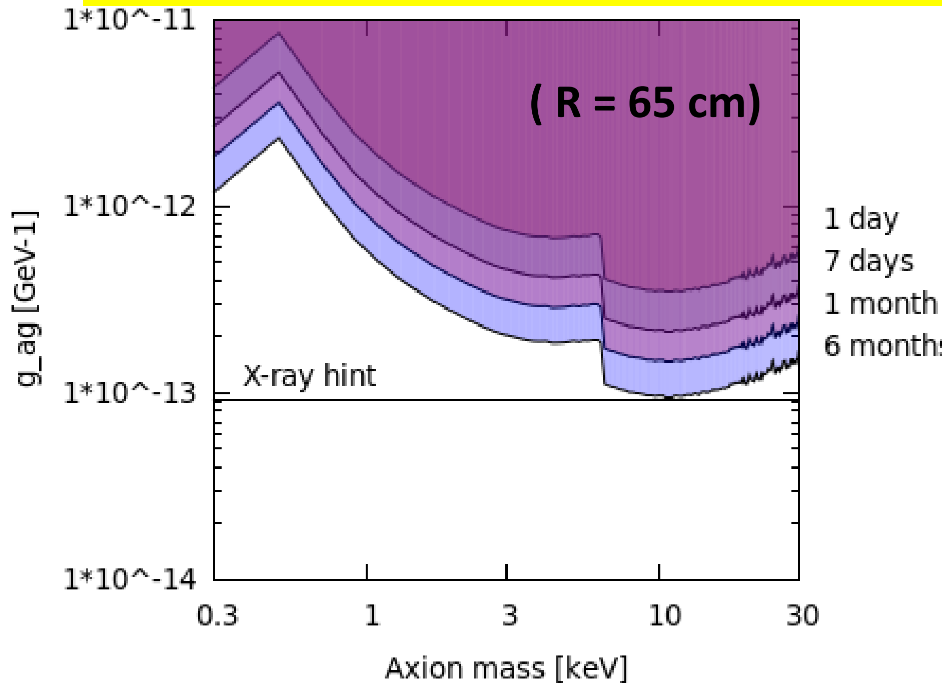
$$\rho_a = 1.18 \times 10^{39} \left(\frac{g_{a\gamma}}{\mathrm{GeV}^{-1}}\right)^2 [\mathrm{m}^{-3}]$$

$$\tau_a = 1.35 \times 10^5 \left(\frac{g_{a\gamma}}{\mathrm{GeV}^{-1}}\right)^{-2} \left(\frac{m_a}{\mathrm{eV}}\right)^{-3} \mathrm{s}$$

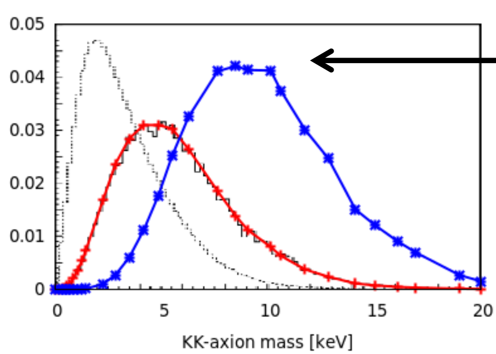
$$N_\gamma = \tau_a^{-1} \cdot \rho_a \cdot V_{Sph} \cdot T_{exp} \cdot \epsilon_{det}$$

Spherical TPC allows to perform a search for this kind of particles. **Large volume, low energy threshold, good rejection capabilities.**

Our sensitivity only 2-prong events contribution



KK-axions tower of mass states

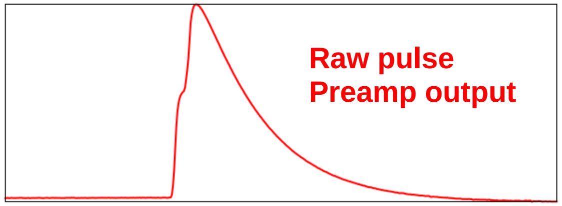


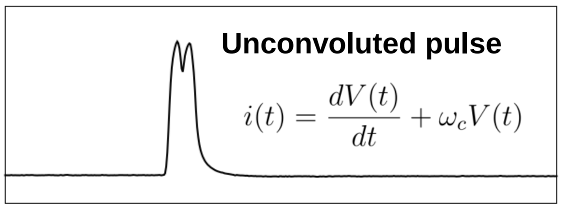
Expected X-ray distribution due to decay dependency with the mass

Detecting 2-prong events

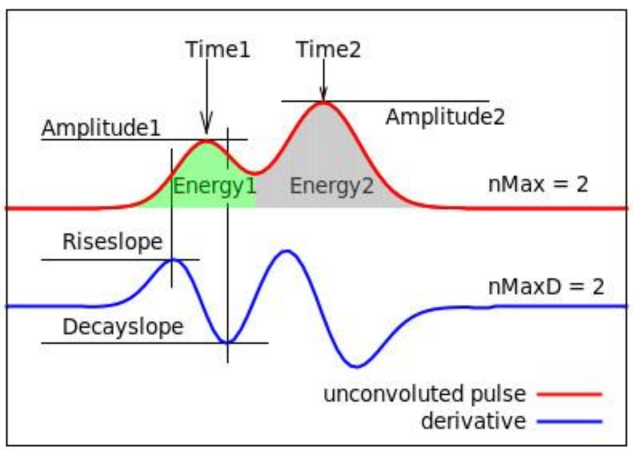
Digitisation @ 1 MHz, soft trigger

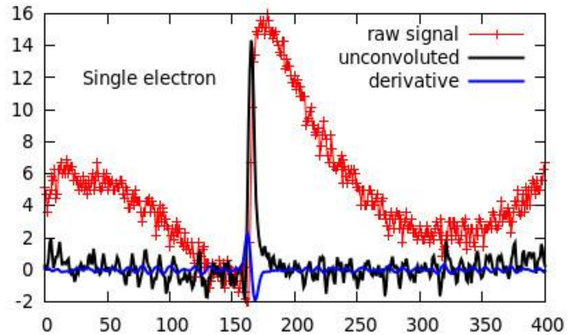
RC integration removed

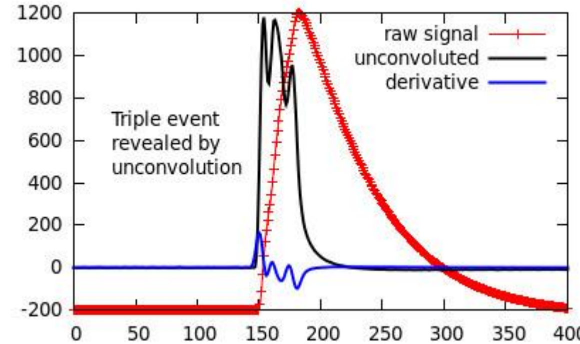




Pulse parameters definition





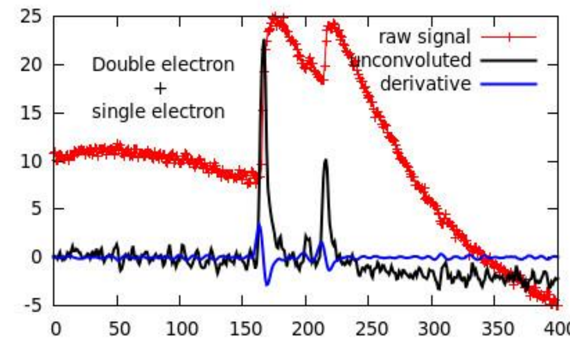


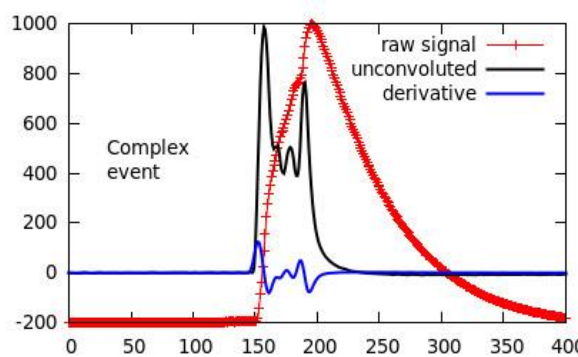
Close hist (within 5us) can be identified

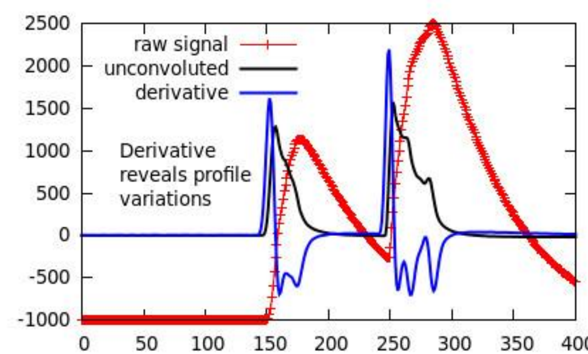
Pulse unconvolution is used to identify peak position in time.

Derivative helps to discover profile variations or very close events.

Extremely low electronic noise! 1 electron equivalent energy is observed clearly!

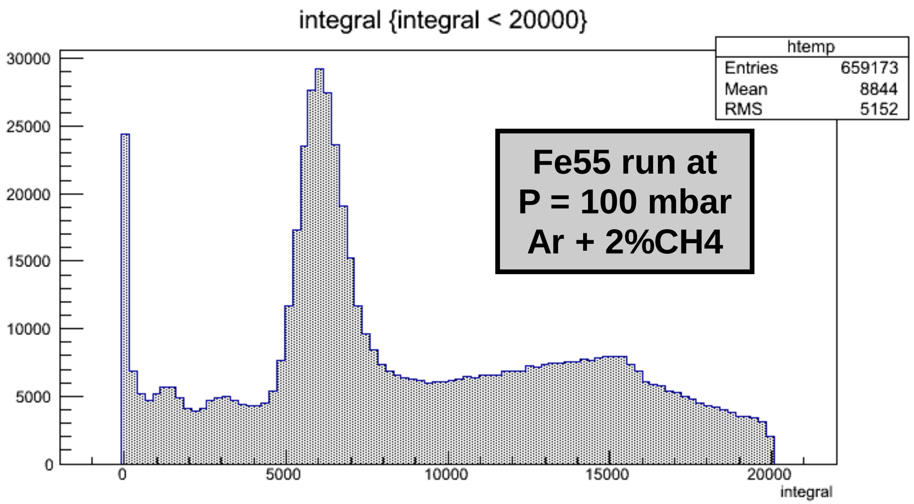




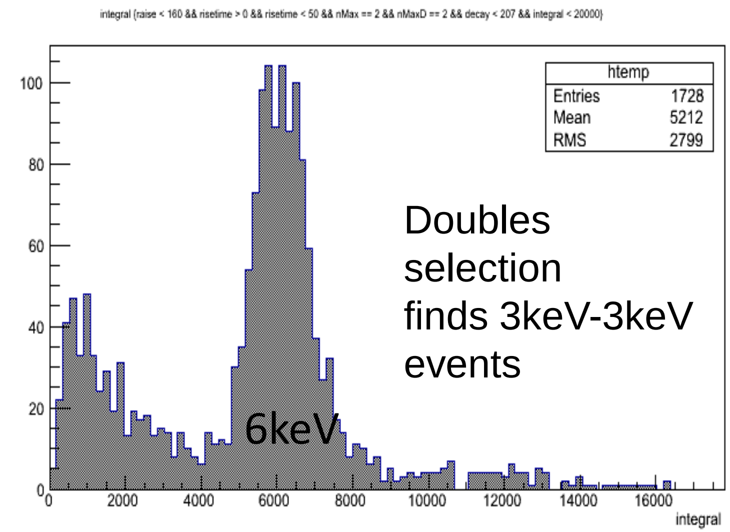


2-prong events observed from a 55Fe source in Argon

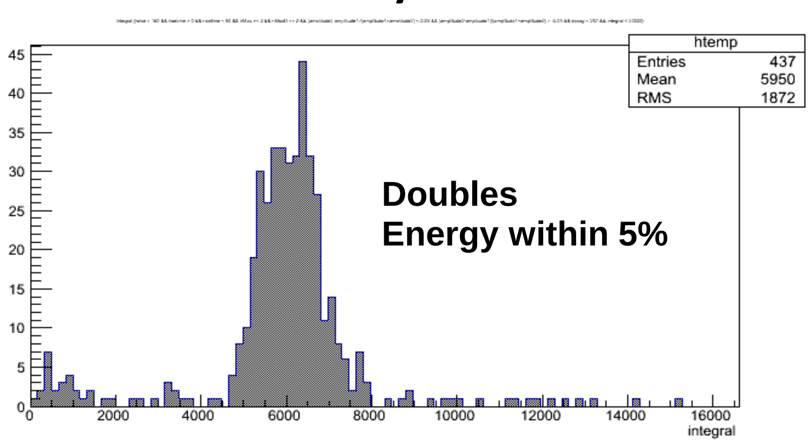
Full Spectrum without cuts (Cosmics + Fe55 peak)



Only doubles spectra

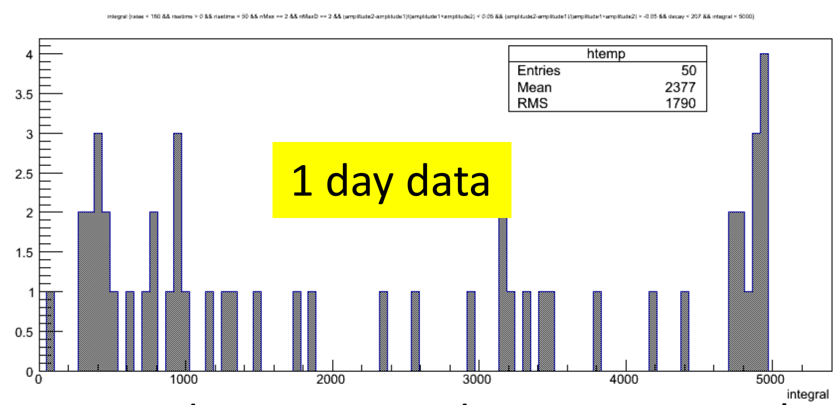


Enhancement for decay search we only need VOLUME



6keV

Very low background rates for doubles events **even at ground level**

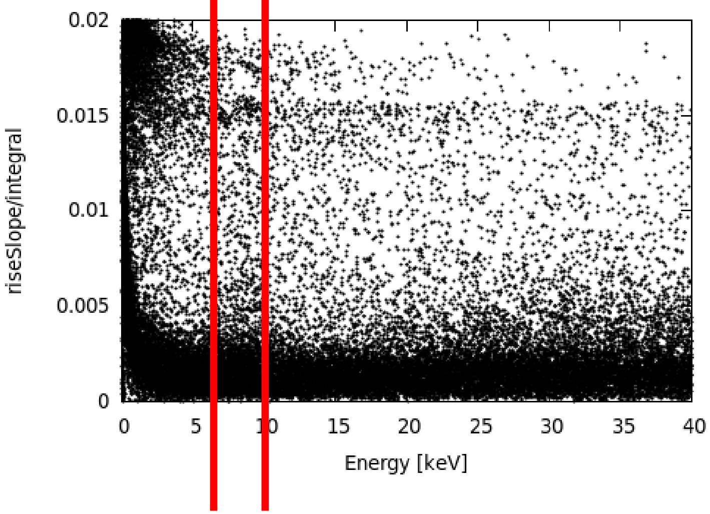


1keV 3keV 6keV

Background discrimination LSM 500 mbar Ar+2%CH4

Copper

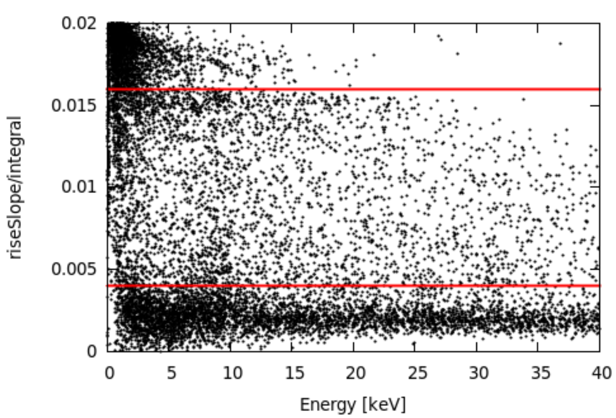
All the events



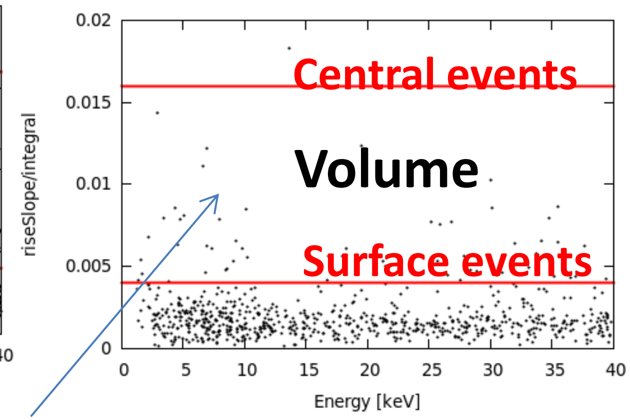
Riseslope depends strongly on the distance to the sensor, due to diffusion.

Enhances for selection of a fiducial volume

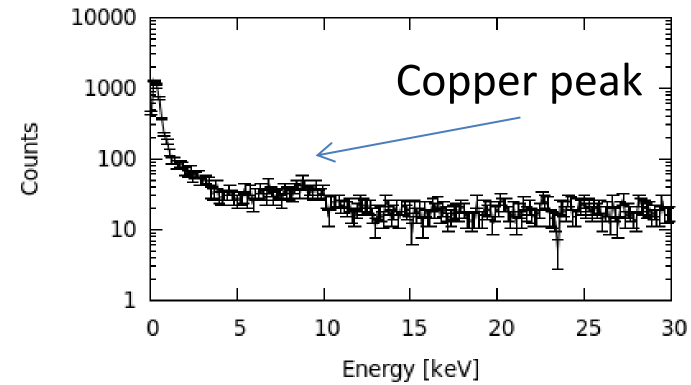
Pure single events

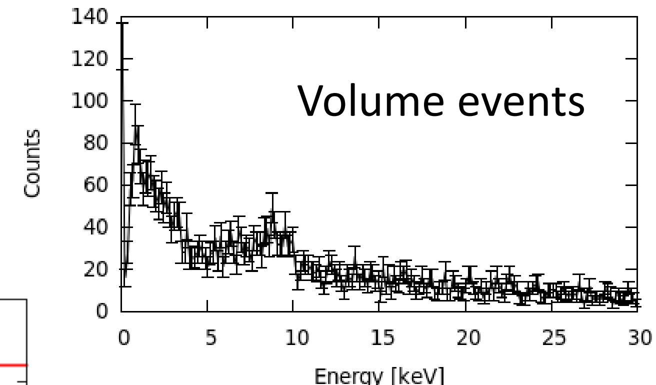


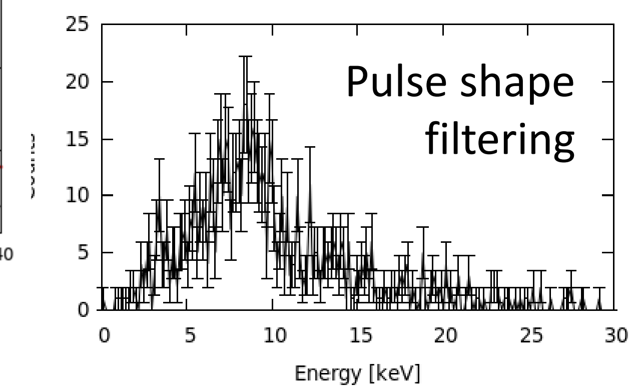
Pure double events



Pure single events spectra







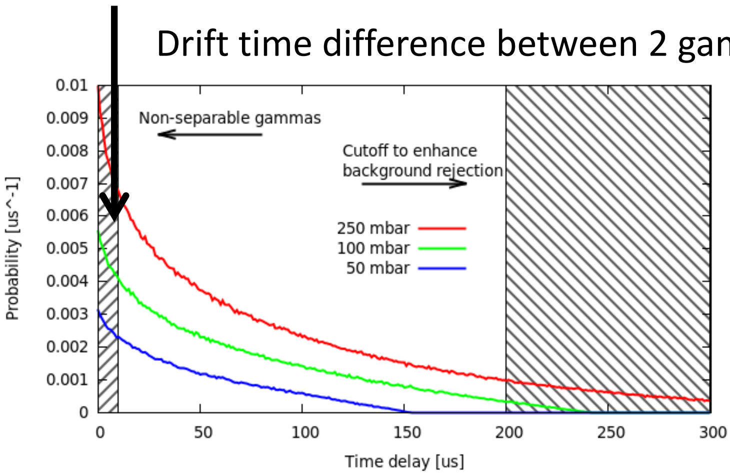
Very low background for 2-prong events

Optimum pressure including diffusion

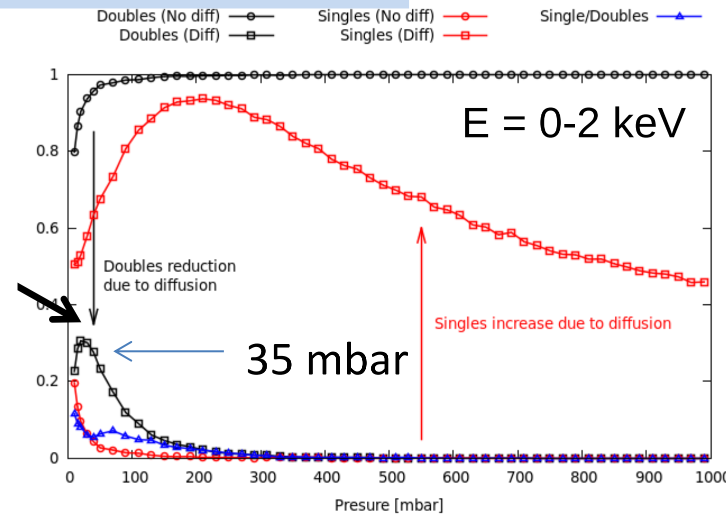
Great flexibility in gas mixture and pressure

Too close events (< 5us)

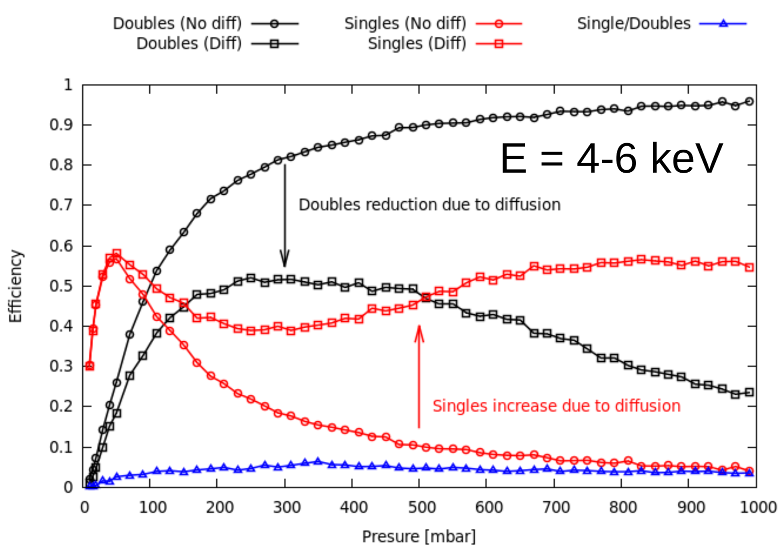
Drift time difference between 2 gammas

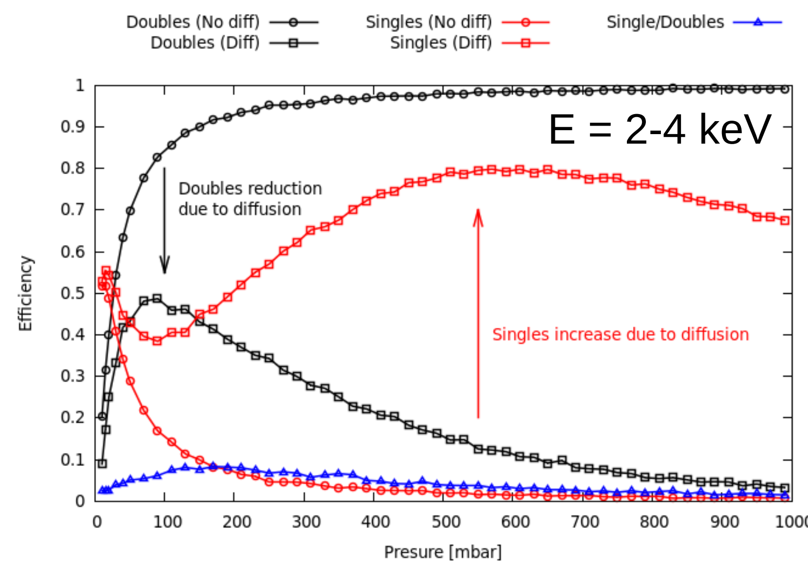


Double det.
At low E
Requires
Low P



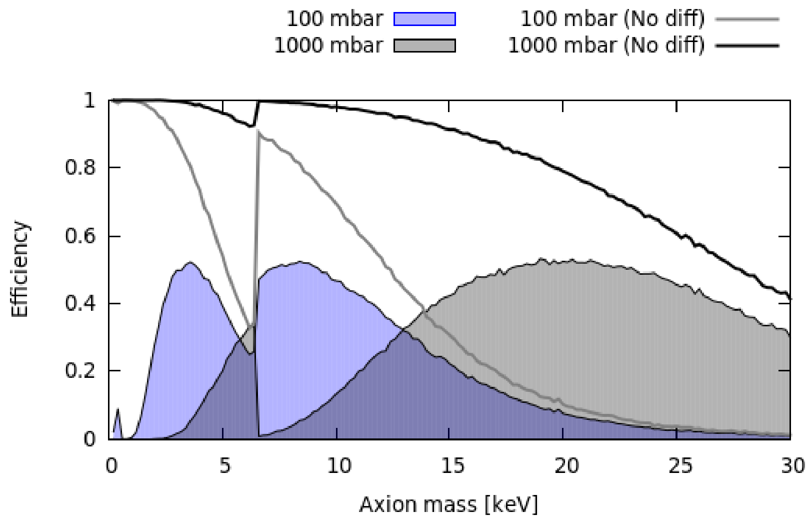
Pressure changes are equivalent to switch OFF/ON the signal!!



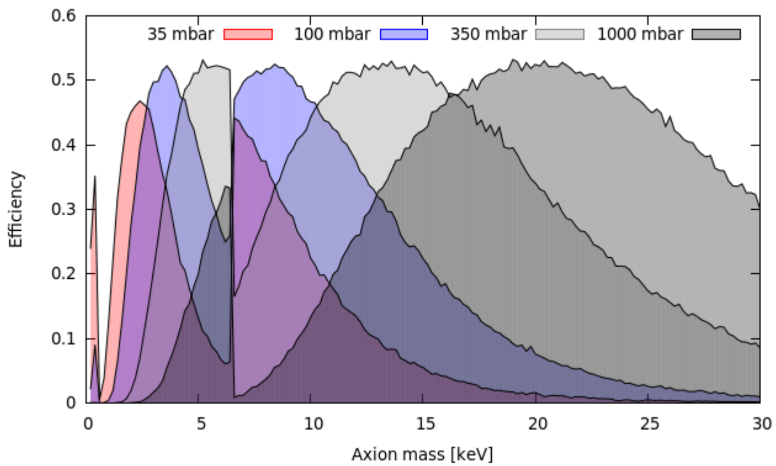


Sensitivity prospects to KK-axions (R=6.5m)

Doubles efficiency @1bar



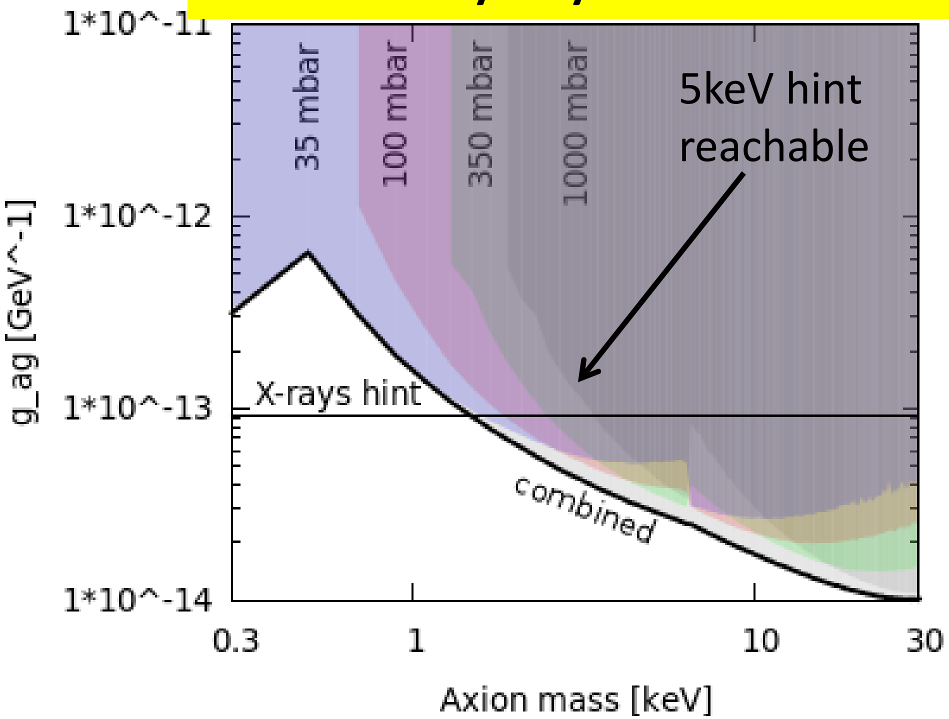
Play with pressure to get a smoother energy scan



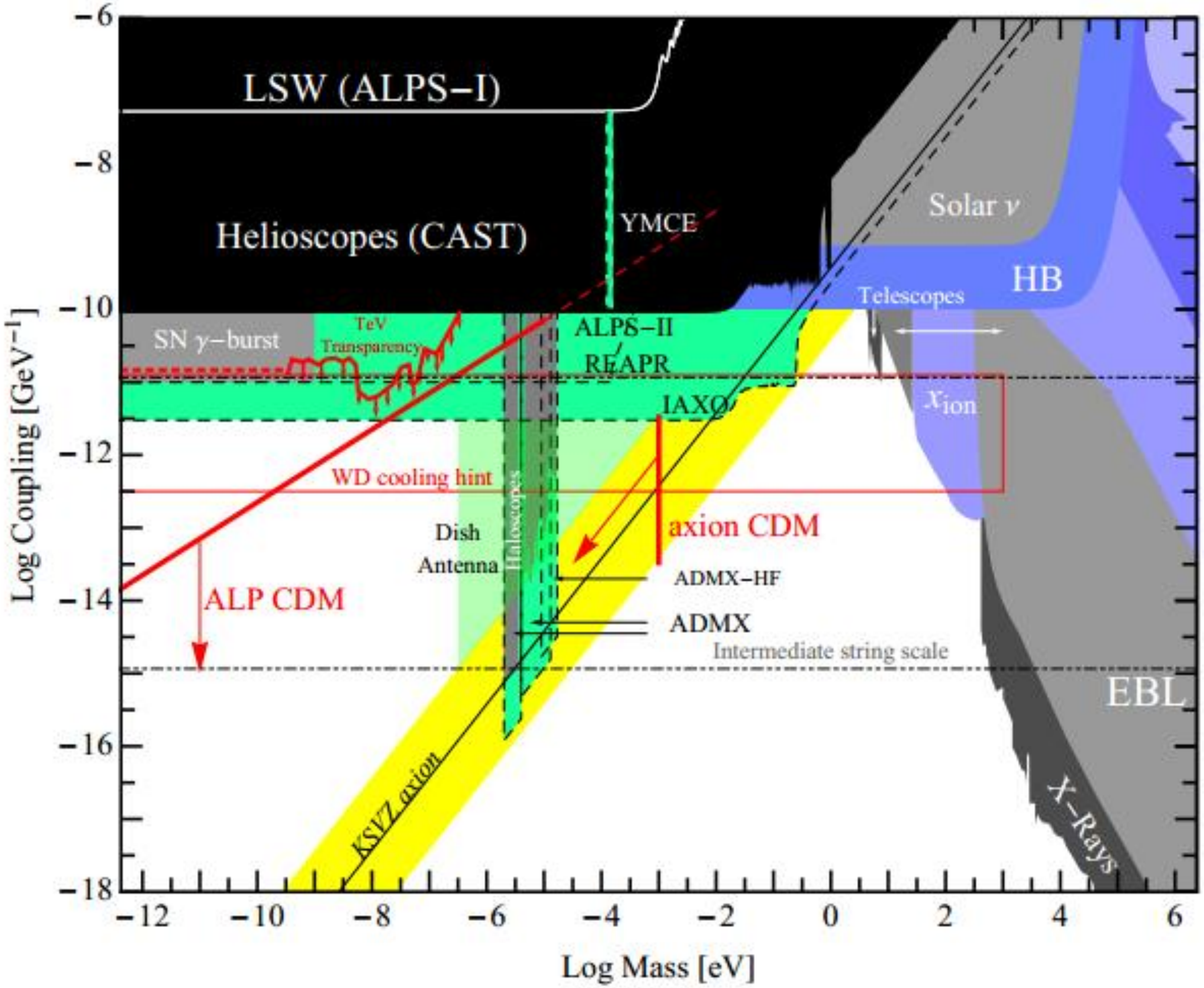
A tentative long data run scanning At 4 different pressures

30 days each pressure 6.5 m

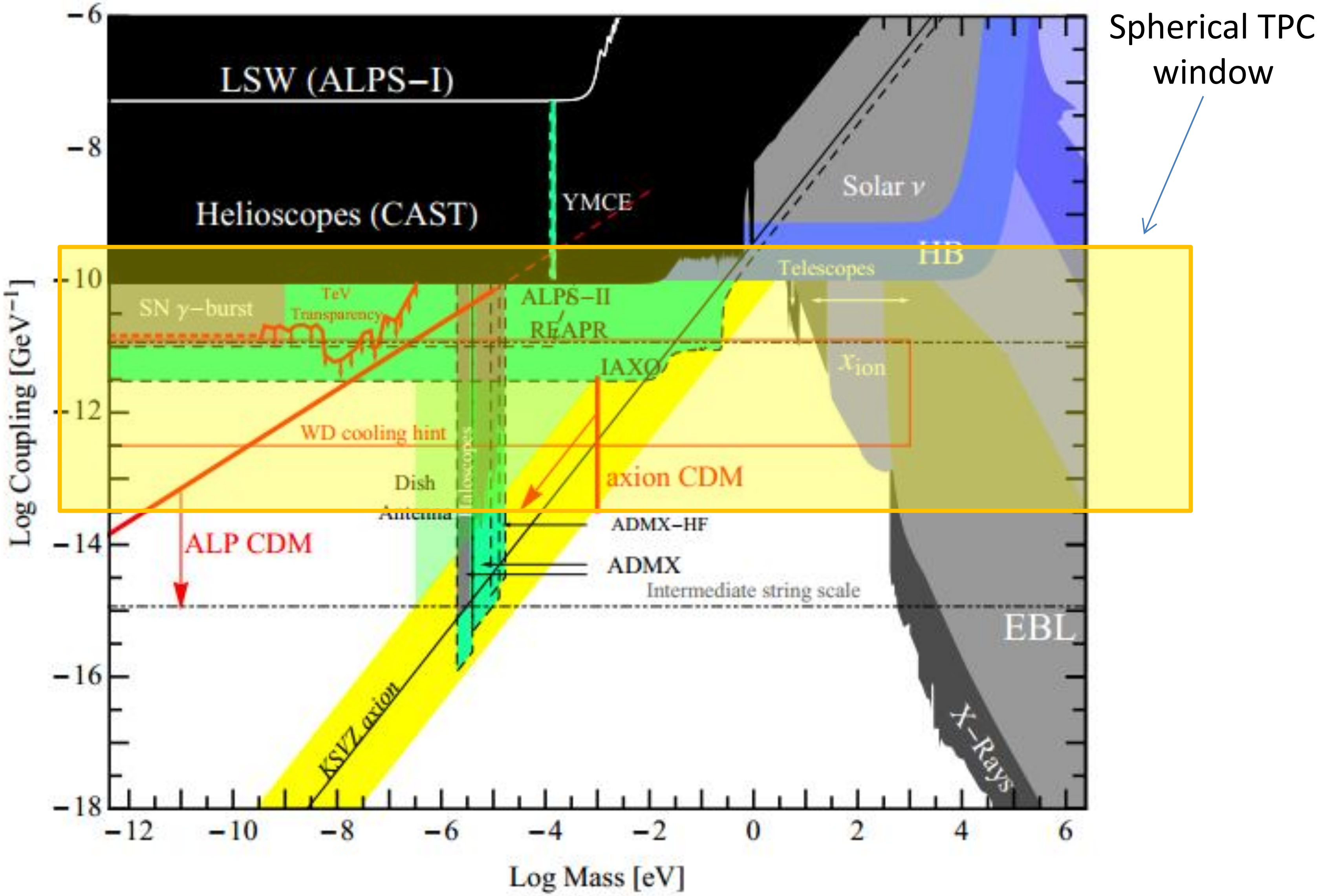
Our sensitivity only doubles contribution



Axion Roadmap



Axion Roadmap



BACKUP

A dedicated Supernova detector

Simple and cost effective - Life time >> 1 century

Through neutrino-nucleus coherent elastic scattering

Y. Giomataris, J. D. Vergados, Phys.Lett.B634:23-29,2006

Sensitivity for galactic explosion

For p=10 Atm, R=2m, D=10 kpc, U_ν =0.5x10^{53} ergs

 # Number of events (no quenching, zero threshold)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
.16	3.95	19.1	76.8	235	179

 # Number of events (after quenching, E_{th} =0.25 keV)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
0.08	1.5	6.7	23.8	68.1	**51.8**

Destruction of massive star initiated by

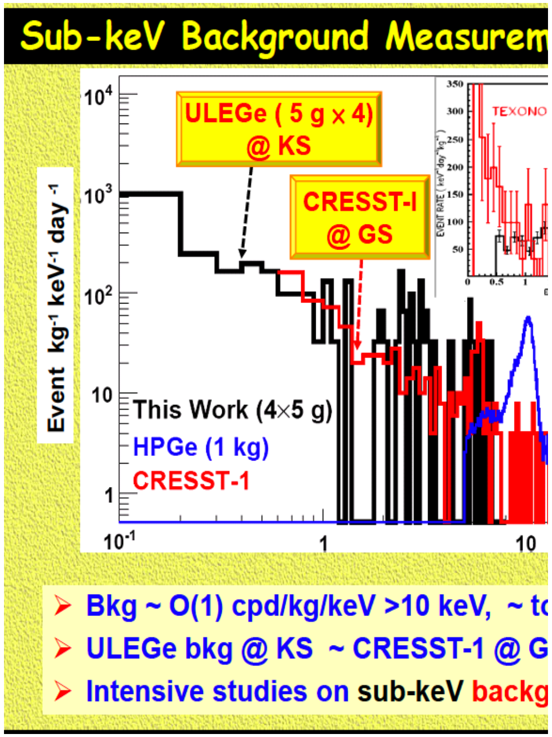
the Fe core collapse

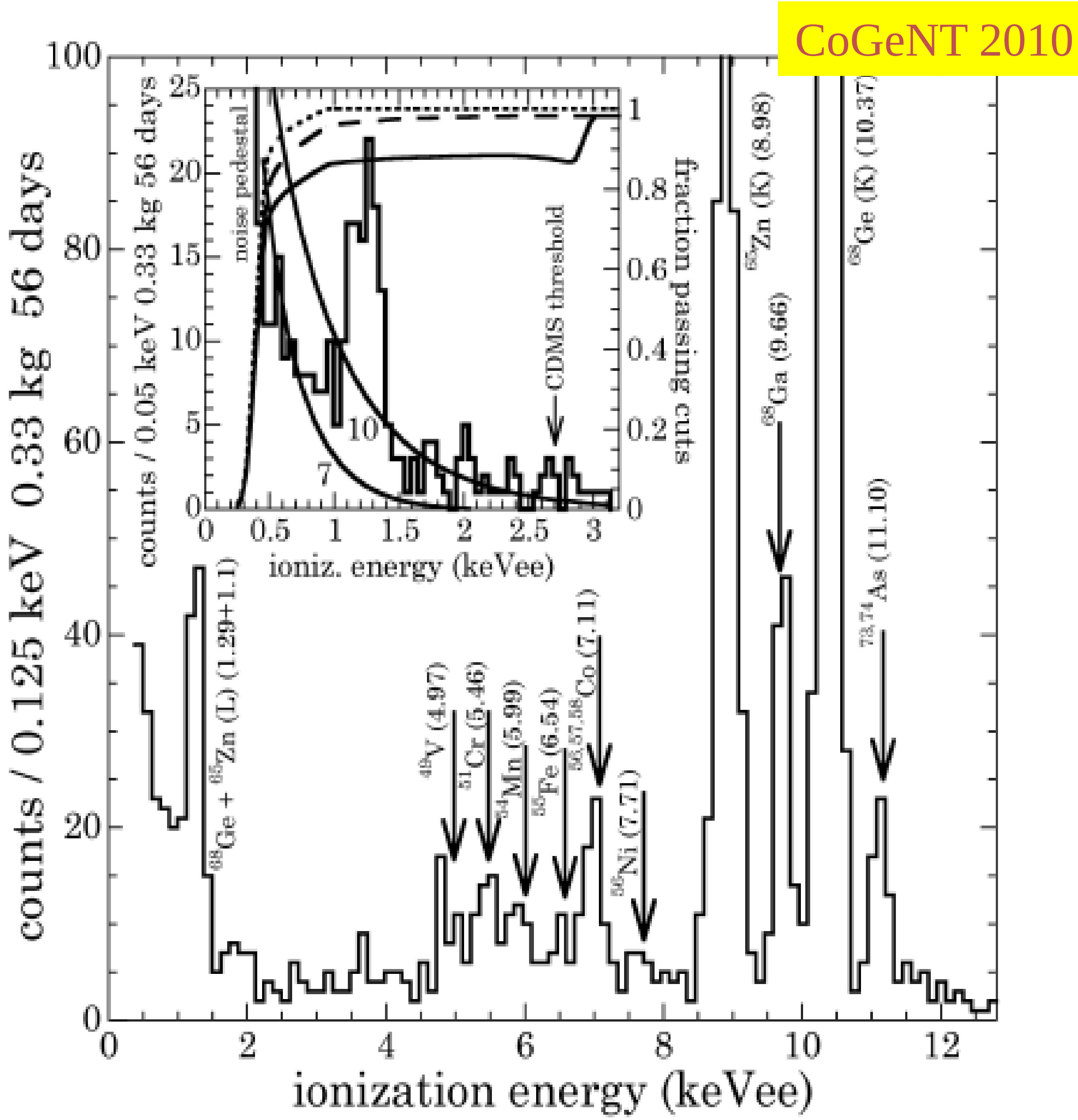
- 10^{53} ergs of energy released
- 99% carried by neutrinos
- A few happen every century in our Galaxy, but the last one observed was over 300 years ago

Idea : A world wide network of several (tenths or hundreds) of such dedicated Supernova detectors robust, low cost, simple (one channel)

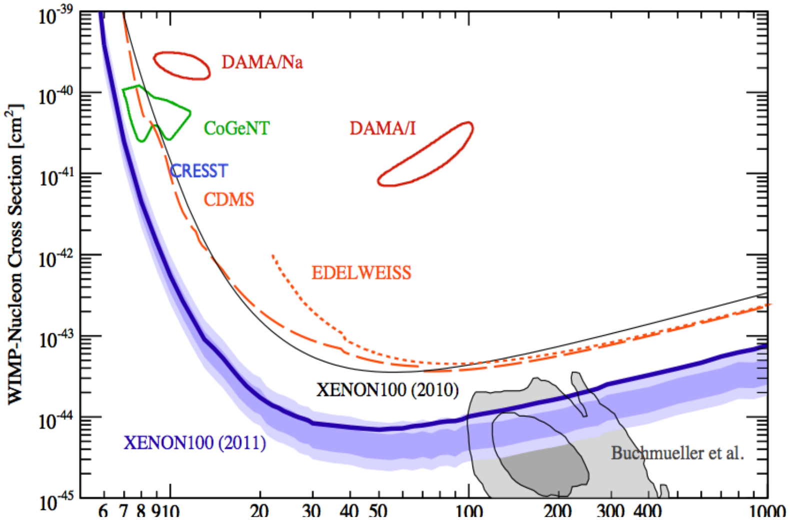
To be managed by an international scientific consortium and operated by students

Dark matter search through very low energy threshold < 100 eV





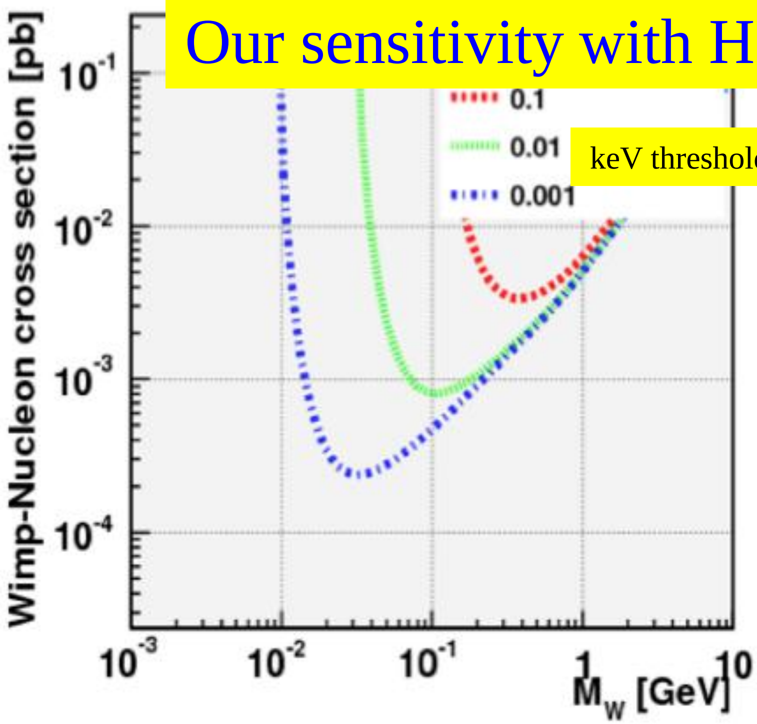
BUT, DAMA and COGENT claim rejected?



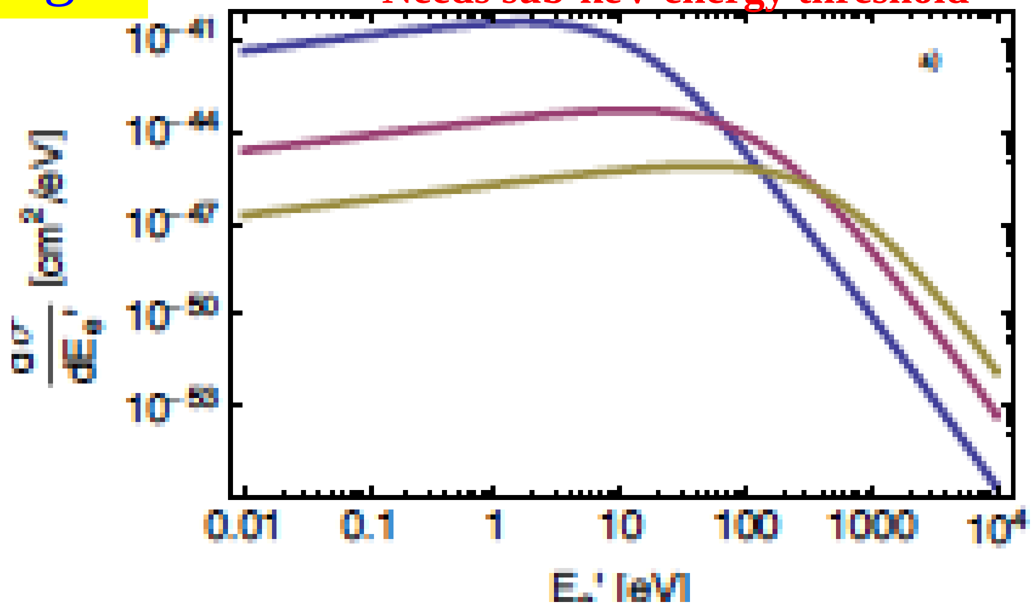
Light Dark Matter candidates

- Light scalars or fermions (Fayet, Boehm&Fayet)
- Kaluza-Klein Axion like Particle
- Electron-Interacting dark matter
- Secluded WIMP dark matter (Arkani-Hamed, Pospelov, Ritz, Voloshin)

Our sensitivity with H target



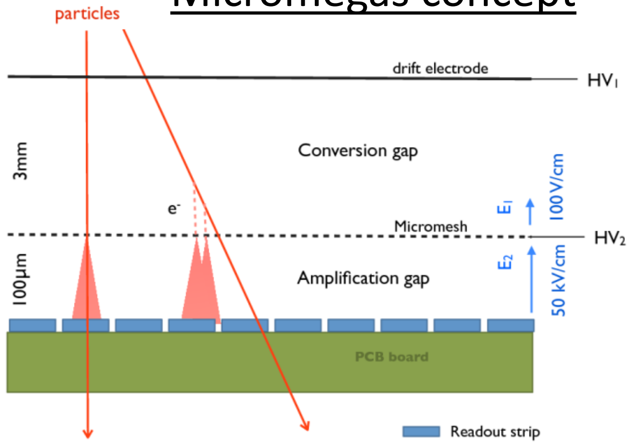
Needs sub-keV energy threshold



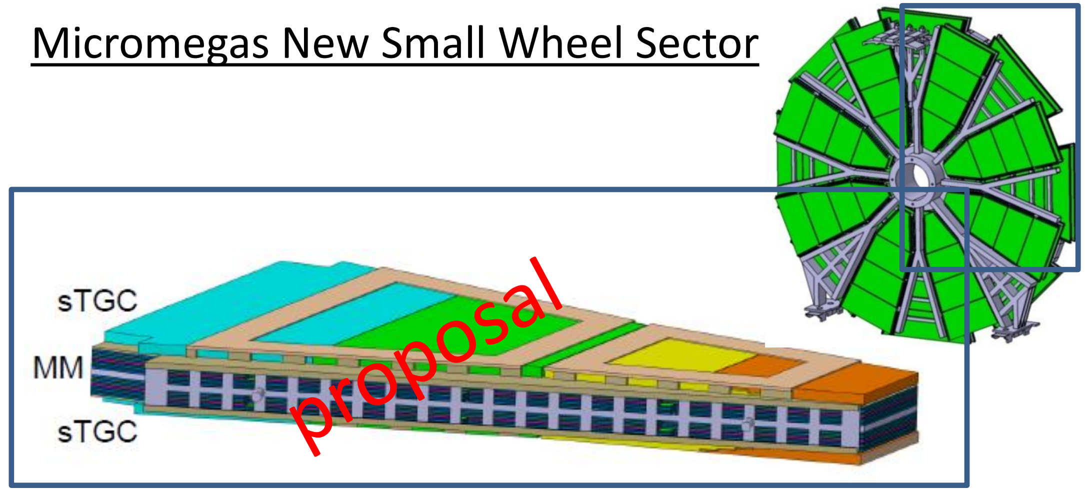
A. Dedes, I. Giomataris,, K. Suxho, J.D. Vergados, Nucl.Phys.B826:148-173,2010

Micromegas detectors for the new small wheel

Micromegas concept



Micromegas New Small Wheel Sector



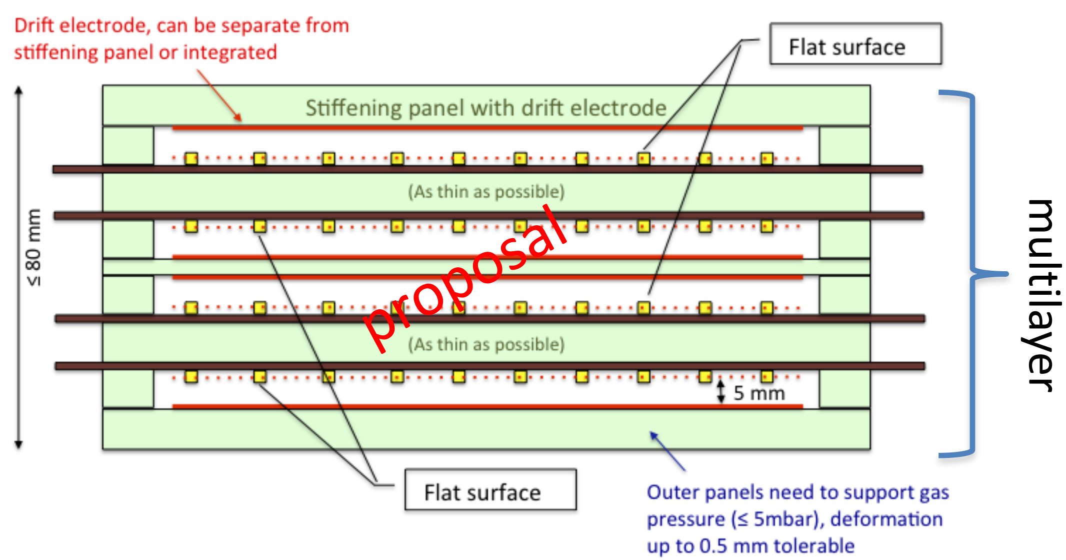
Multilayer description

•Each detector comprises eight active layers, arranged in two multilayers.

•The basic detector unit is an assembly of four layers that form a stiff multilayer.

•The individual layers should be arranged in two doublets in which the Micromegas are mounted back-to-back

•The flat surfaces of all layers should be parallel to within 40–60 µm and the strips in all layers must be parallel with the same precision.



Some experiments using
Bulk Micromegas

ATLAS-SLHC

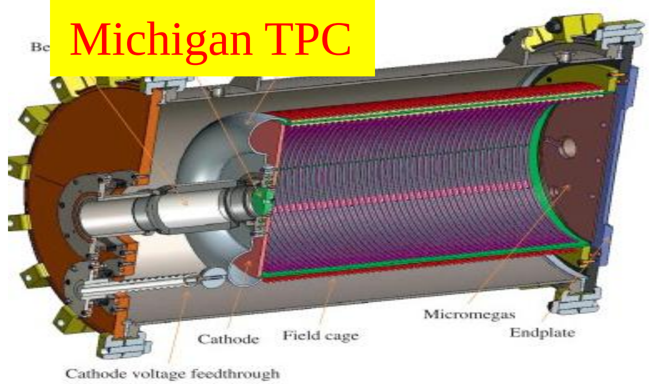
Very-large

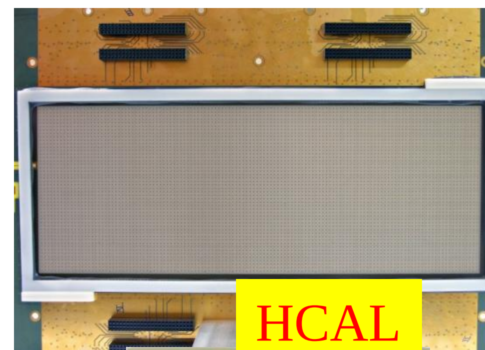
T2K

CLAS12G

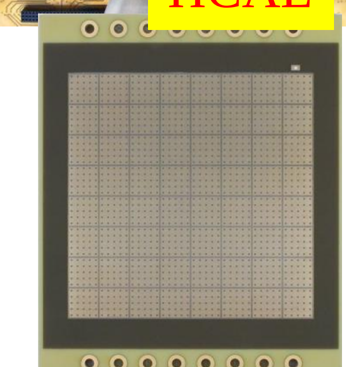
ILC/TPC

Michigan TPC





HCAL



ATLAS large chambers

Industrialization is going on
Through CIREA, ELTOS,
Triangle Labs (US)

1 x 1 m^2 micromegas

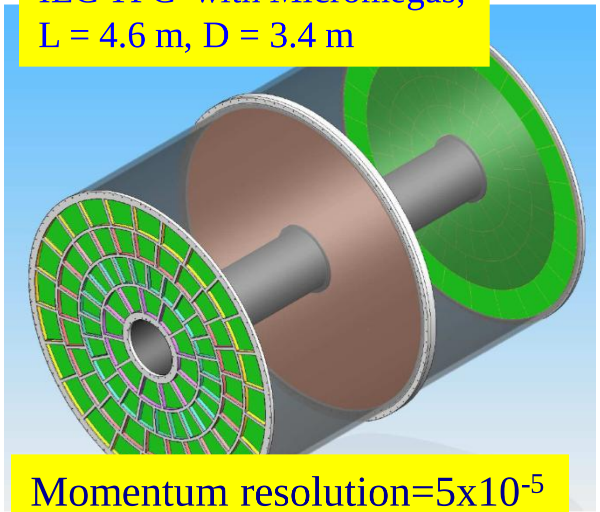
1 x 1 m^2 readout board composed of 2 boards of 0.5 x 1 m^2
2048 strips of 1.06 m length with a pitch of 0.45 mm

Drift electrode and mesh panel (top) and
detail showing the O-ring as gas seal

ILC TPC project - *Large International collaboration*

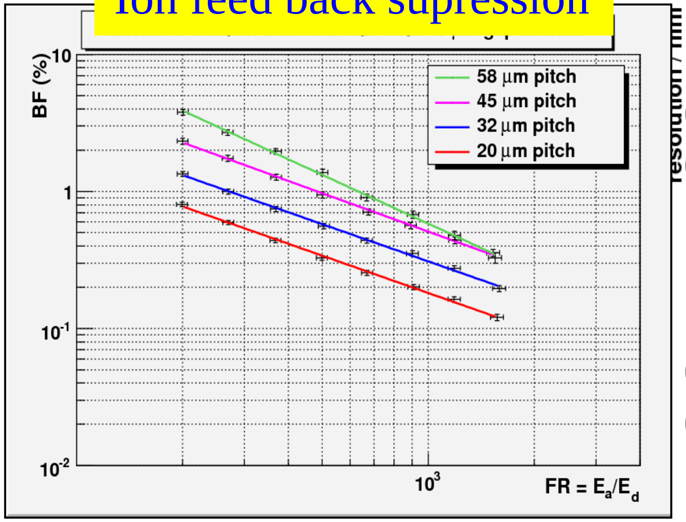
G. Aarons et al., arXiv:0709.1893, M. S. Dixit et al., NIMA 518 (2004) 521, M. Kobayashi et al.,NIMA581(2007)265, D. Arogancia et al.,NIMA602(2009)403

ILC TPC with Micromegas,
L = 4.6 m, D = 3.4 m

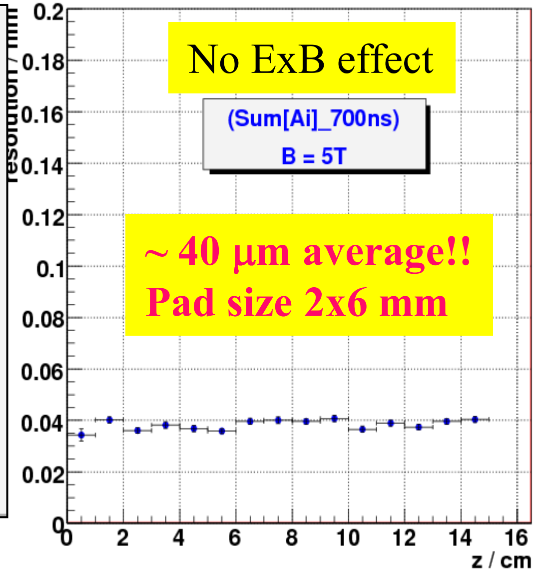


Momentum resolution=5x10^{-5}

Ion feed back supression



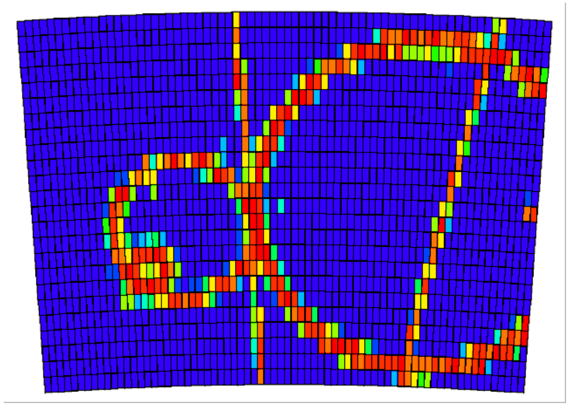
No ExB effect



~ 40 μm average!!
Pad size 2x6 mm

ILC TPC prototype
with Micromegas

Event in DESY test beam



TPC requirements

- gain < 1500
- Ion suppression
- Large surface
- Good uniformity

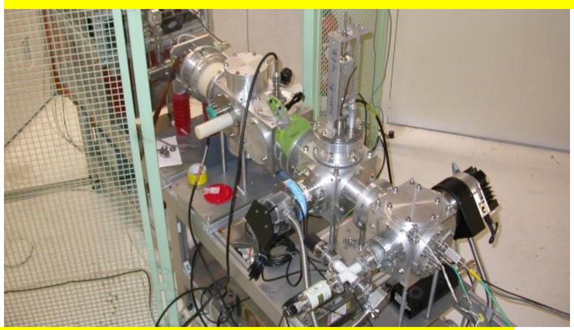
MIMAC-He3 MIcro-tpc Matrix of Chambers of He3

WIMP directional TPC, Micromegas read-out,

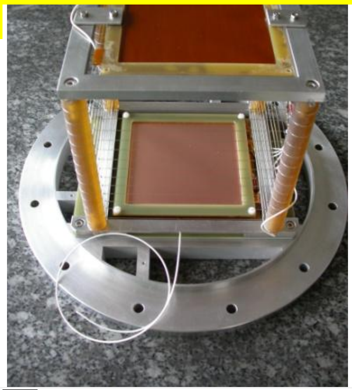
Grenoble – Saclay, Cadarache collaboration

C. Grignon et al., JINST 4 (2009) P11003

Quenching factor measurement



Micromegas:µTPC chamber

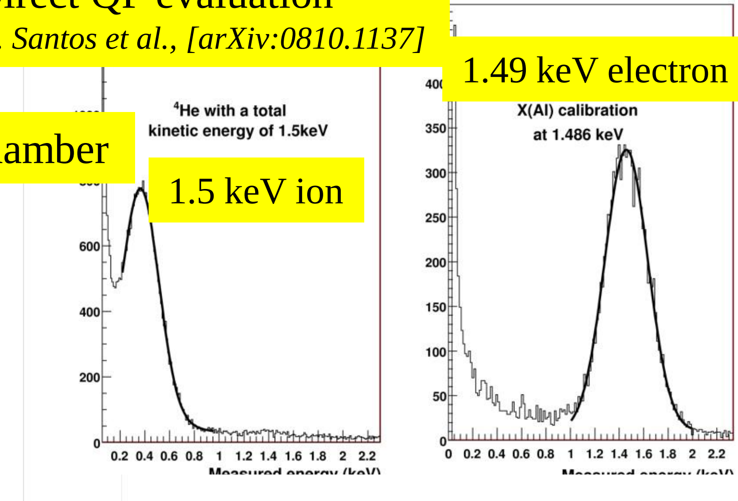


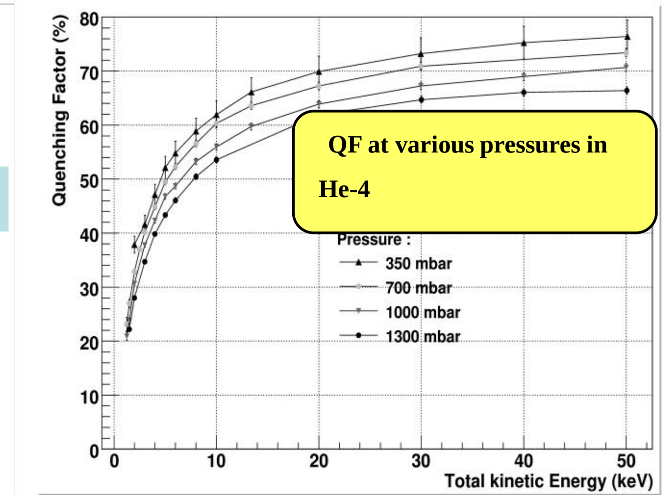
Direct QF evaluation

D. Santos et al., [arXiv:0810.1137]

1.5 keV ion

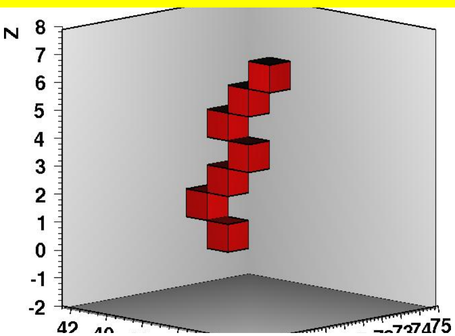
1.49 keV electron



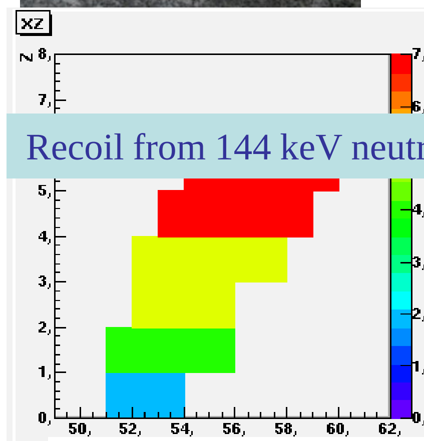


QF at various pressures in He-4

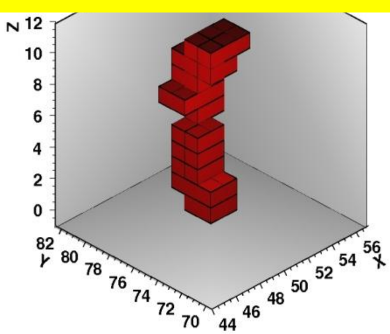
proton 8 keV, He + 5% iC_4H_{10}, 350 mbar



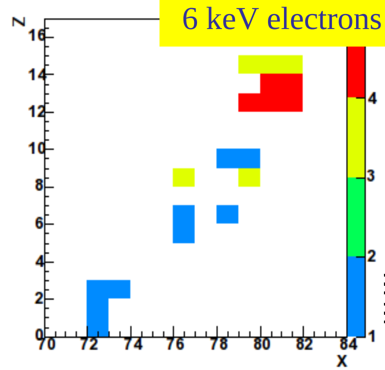
Recoil from 144 keV neutrons

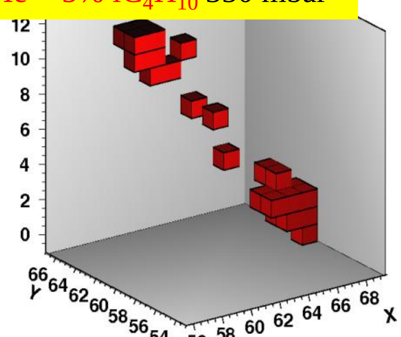


40 keV ^{19}F, 70 % CF_4 + 30% CHF_3 , 55 mbar



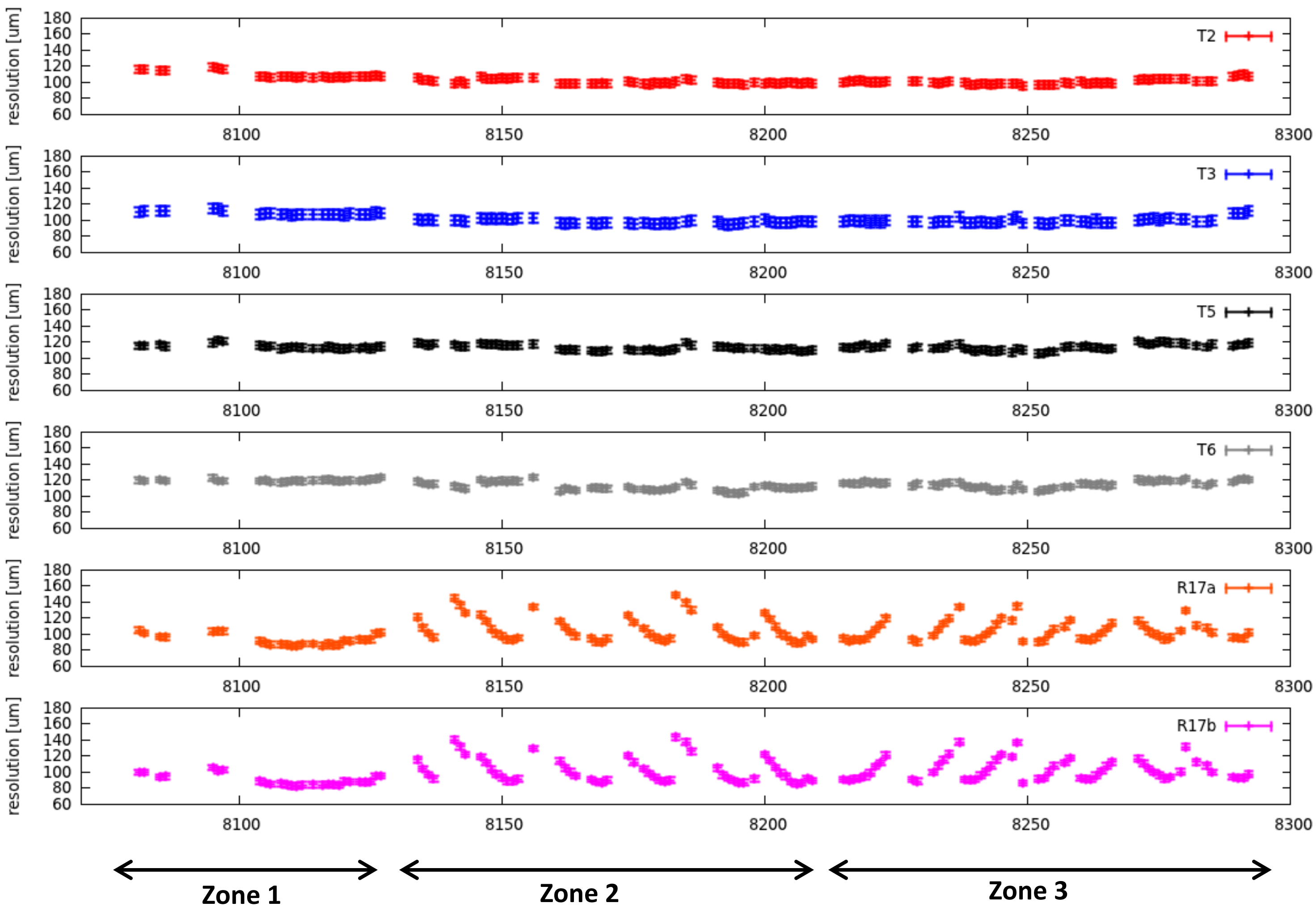
6 keV electrons in He + 5% iC_4H_{10} 350 mbar





Beam tests took place at the end of October 2012. During two weeks R17 detectors took data. Three different zones were irradiated. And different settings were taken at each of these beam exposed regions.

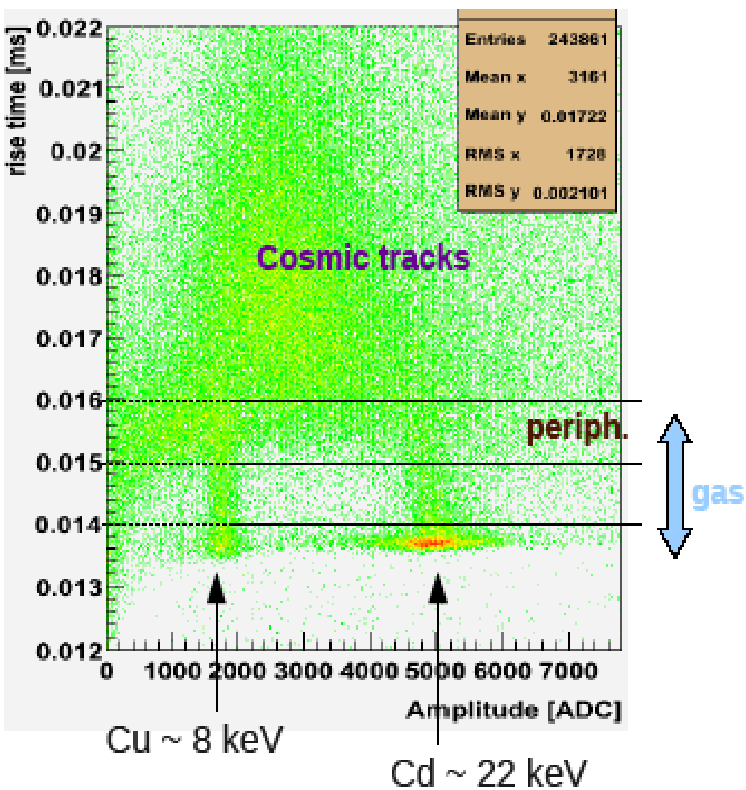
Spatial resolution history for the different runs taken during this period.

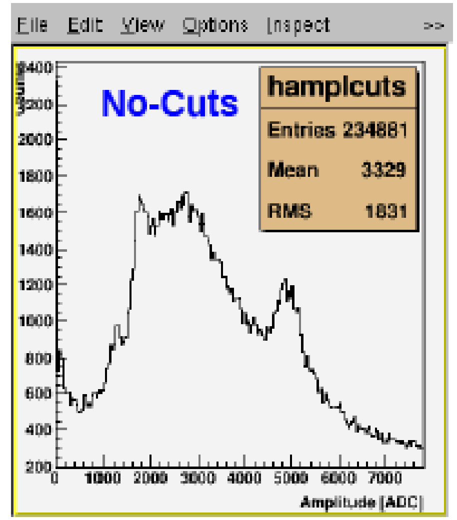


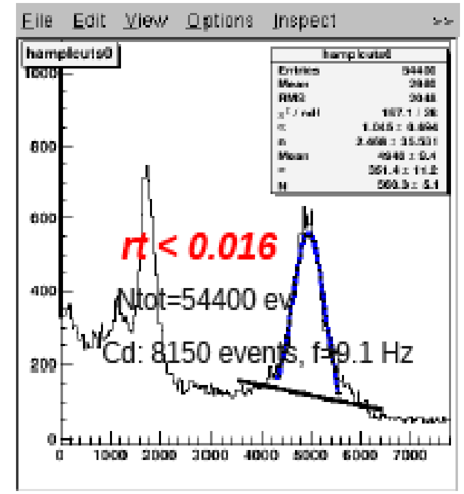
Rejection power

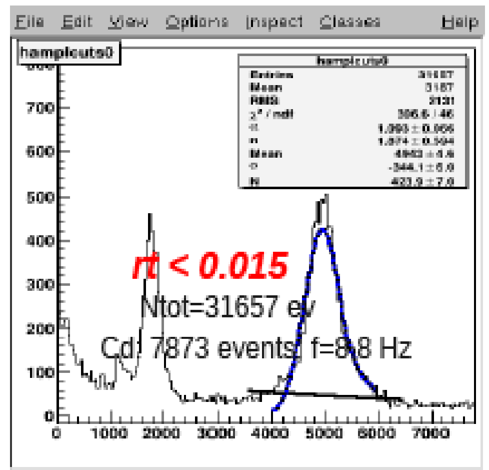
Rise time cut

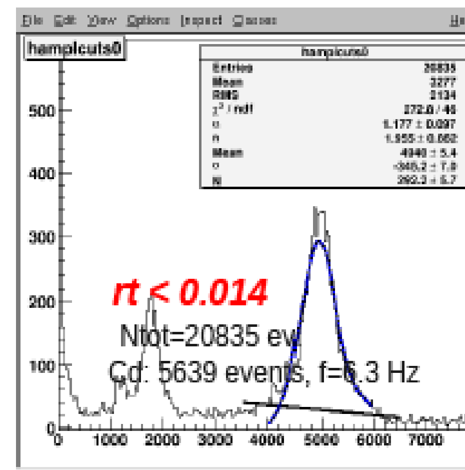
Using Cd-109 source – December 2009
Irradiate gas through 200µm Al window
P = 100 mb, Ar-CH_4 (2%)











If rt ~ 0.0155 ms ==> R = 65 cm
0.014 ms ==> ~70% of signal

Efficiency of the cut in rt ==> ~ 70% signal (Cd peak)

Severe background reduction

Energy resolution ~ 6 % and 9 % for Cu and Cd

Ultra low energy threshold observed

arXiv:1010.4132 [physics.ins-det], 2010